REPORT OF INVESTIGATION 22

GEOLOGY AND GEOCHEMISTRY OF THE POKIOK BATHOLITH NEW BRUNSWICK

by

G.G. Lutes

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HON. MALCOLM N. MacLEOD, MINISTER

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ABSTRACT

The Pokiok Batholith is divisible into the Hartfield Tonalite, and the Skiff Lake and Hawkshaw granites. Each has distinctive aeromagnetic expression, and macroscopic, microscopic, and petrochemical characteristics. The megacrystic Skiff Lake and Hawkshaw granites constitute the bulk of the batholith. These two are petrographically and compositionally similar but the latter intrudes the former. Both have been subdivided into a number of phases and each contains a relatively younger core of equigranular muscovite-biotite granite which is the most felsic of the plutonic phases. The relatively older Hartfield Tonalite is more mafic than the Hawkshaw and Skiff Lake granites. Abundant hypabyssal leucogranitic dykes have intruded along the margins of the batholith north of the Saint John River and postdate the plutonic rocks.

The granites of the Pokiok Batholith are derived from a mixture of igneous and sedimentary material. Geochemically, they are intermediate between plumasitic and palingenic intrusions. The depth of intrusion at the present level of erosion is probably on the order of 10-15 km, whereas the hypabyssal dykes at the margins of the batholith indicate a higher level of intrusion during the waning stages of magmatism. The granites of the Pokiok Batholith lack the high degree of trace-element specialization that is characteristic of tin-bearing granites.

Scheelite occurs in skarn in the Lake George antimony deposit and in calc-silicate hornfels and granite in the Coac Stream area. This mineralization postdates the youngest phases of the Pokiok Batholith.

RÉSUMÉ

Le batholite de Pokiok se divise entre la tonalite de Hartfield d'une part, et les granites du lac Skiff et de Hawkshaw d'autre part. Chacune des parties comporte ses propres caractéristiques aéromagnétiques, macroscopiques, microscopiques et pétrochimiques. Les granites mégacrystiques du lac Skiff et de Hawkshaw forment la majeure partie du batholite. Ces deux formations sont semblables du point de vue de la pétrographie et de la composition, mais la deuxième formation fait intrusion dans la première formation. Les deux peuvent se subdiviser en un certain nombre de phases et chacune contient un noyau relativement plus récent de granite isogranulaire de type muscovite-biotite, noyau qui constitue la phase la plus felsique des phases plutoniques. La tonalite de Hartfield, relativement plus âgée, comprend plus de roches mafiques que les granites de Hawkshaw et du lac Skiff. Des dykes de roches hypabyssales leucogranitiques, postérieures aux roches plutoniques et que l'on retrouve en abondance, ont fait intrusion sur les bords du batholite nord du fleuve Saint-Jean.

Les granites du batholite de Pokiok proviennent d'un mélange de matières sédimentaires et éruptives. Du point de vue géochimique, ils se situent entre les intrusions plumasitiques et les intrusions palingéniques. Au présent stade de l'érosion, la profondeur de l'intrusion est probablement de l'orde de 10 à 15 km, alors que les dykes hypabyssales sur les bords du batholite indiquent un niveau supérieur d'intrusion lors des derniers stades du magmatisme. Les granites du batholite de Pokiok ne sont pas marqués par une quantité élevée d'éléments en traces qui est caractéristique des granites stannifères.

On trouve la scheelite dans le skarn du gisement antimonieux du lac George et dans les cornéennes à silicates calciques et le granite de la région du ruisseau Coac. Cette minéralisation est portérieure aux phases plus récentes du batholite de Pokiok.

GEOLOGY AND GEOCHEMISTRY OF THE POKIOK BATHOLITH NEW BRUNSWICK

INTRODUCTION

The Pokiok Batholith is located in west-central New Brunswick and underlies an area of about 1570 km^2 (Figure 1). Most of the batholith lies south of the Saint John River and is accessible via the Trans-Canada Highway between Woodstock and Fredericton. Secondary roads provide adequate coverage in most areas with the exception of a large area west of Magaguadavic Lake and the area south of Musquash Lake. The portion of the batholith north of the Saint John River is accessible via Route 605 northward through Nackawic and Millville and via Route 104 from Millville to Zealand.

Detailed examination of the Pokiok Batholith was undertaken in response to increased interest in the tin, tungsten, and molybdenum potential of the granitic rocks of west-central New Brunswick. Local scheelite-bearing zones are known to exist in the Coac Stream area east of Nackawic and in the contact aureole of the batholith northwest of the Lake George antimony mine.

PREVIOUS WORK

Early workers in the Pokiok area included Hind (1865), Robb (1870), Bailey (1885), and Ells (1907). H.Y. Hind, in examining the rocks along the Saint John River, described the granite as "very porphyritic" containing large crystals of feldspar up to one and one-half inches long. He noted the "parallelism of the alternating belts of schist and granite" near the Shogomoc River and suggested that these were "altered sedimentary strata, changed by metamorphism into plastic feldspathic sandstones and granitoid gneiss, then by a further metamorphism, partly into plastic granite and in part retaining traces of the stages of their metamorphism". Robb (1870) also noted the included bands of "gneissoid rock" in the granite. Bailey (1885) considered these to be "detached masses" of metamorphosed country rock and inferred from this an intrusive origin for the granite.

More recently, maps and compilations of parts of the batholith have been published. Tupper (1957) mapped the Fosterville area. Patterson (1957, 1958) produced maps of the Canterbury area and found fossils indicating an Upper Silurian to Lower Devonian age for rocks in the contact aureole, thus placing a maximum age limit on the granite. Rutledge (1957) examined the batholith along the Saint John River and found it to be mainly a porphyritic quartz monzonite with granodiorite on its western margin. A biotite-hornblende-bearing intrusion on the Shogomoc River was classified by Rutledge as a lamprophyre. Clark (1959) mapped the McAdam sheet in the southern part of the batholith. The adjacent Forest City sheet was mapped by Smith (1964) who found the batholith to contain mostly grey, porphyritic, muscovite-biotite quartz monzonite. Work by Larrabee et al. (1965) in Maine included the westernmost extension of the batholith. Larrabee noted the local occurrence of rapakivi mantles on alkali feldspar phenocrysts and found that the porphyritic texture of the rock extended to within a metre of the granite contacts. Mapping by F.D. Anderson and W.H. Poole north of the Saint John River is included in a compilation by Anderson and Poole (1959). Anderson (1968) mapped the Millville and Coldstream areas and found the batholith to consist mostly of pink, coarse-grained and locally porphyritic, biotite granite and quartz monzonite. Poole (1957) mapped part of the batholith in the adjacent Burtts Corner sheet and found similar rock types. He noted that contacts with the hornblende-bearing country rock were sharp.

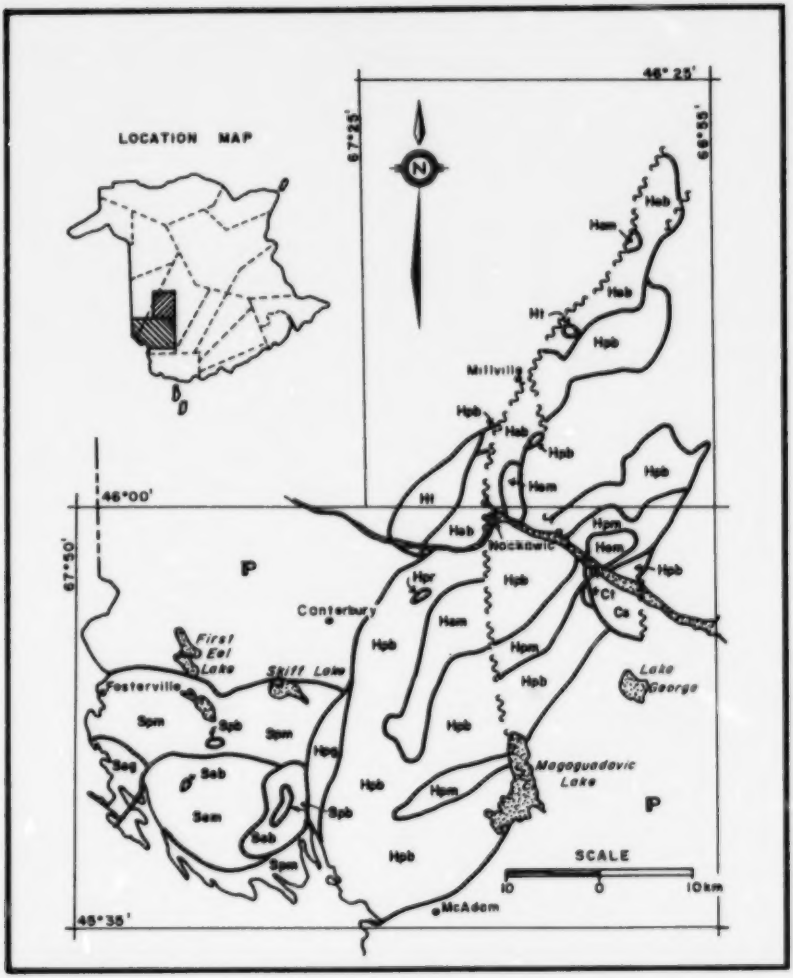

FIGURE 1. Geology of the Pokiok Batholith.

Martin (1970) studied the mineralogy and chemistry of the Pokiok Batholith and classified it as a subsolvus granite. He found obliquity values ranging from 0.34 to 0.37 for potassium feldspars and suggested that "extensive subsolidus recrystallization of initially disordered feldspars" was responsible. It was inferred that "intragranular aqueous fluids attended this extensive subsolidus recrystallization". In comparing the Pokiok and Saint George batholiths, Martin concluded, from the lack of volcanic equivalents and miarolitic cavities, the relative scarcity of rapakivi granite, and the abundance of pegmatite, that the Pokiok Batholith was emplaced at greater depths and at a lower temperature than the Saint George Batholith.

LEGEND

CARBONIFEROUS

Cs | Ct	Cs, grey and brown sandstone and conglomerate; Ct, ash-flow tuff

LOWER DEVONIAN

HAWKSHAW GRANITE

Hem	Grey, medium-grained, equigranular to seriate, muscovite-biotite granite
Hpr	Grey to pink, medium-grained, seriate, rapakivi, biotite granite
Hpm	Pink, medium- to coarse-grained, hiatal, muscovite-biotite granite
Hpb	Pink, medium- to coarse-grained, hiatal megacrystic, biotite granite
Hpg	Grey, coarse-grained, equigranular to porphyritic, biotite granodiorite, locally muscovite-bearing
Heb	Pink, fine- to coarse-grained, equigranular to seriate, biotite granite

SKIFF LAKE GRANITE

Sem	Grey, medium-grained, equigranular, muscovite-biotite granite
Seb	Pink, fine-to coarse-grained, equigranular to seriate, biotite granite
Spb	Grey, fine- to medium-grained, seriate, biotite granodiorite
Seg	Grey, medium- to coarse-grained, equigranular to seriate, biotite granodiorite, locally muscovite-bearing
Spm	Grey, coarse-grained, seriate megacrystic, muscovite-biotite granite

HARTFIELD TONALITE

Ht	Grey, coarse-grained, hornblende-biotite tonalite

PRE-DEVONIAN

P	Paleozoic country rocks

SYMBOLS

——— Geological boundary

∿∿∿ Fault

Garland (1953), from gravity measurements, suggested that the granite extended to a depth of 6 km, and estimated it to dip about 60° to the west. P.H. McGrath (1970), from magnetic susceptibility measurements, showed that the batholith was composed of a southwestern part containing grey adamellite and an eastern part containing pink adamellite.

Rast (1977) inferred from the parallelism of the foliation in the Hartfield Tonalite and the schistosity in xenoliths that the intrusion was pretectonic. O'Brien (1977) concluded that this intrusion was synkinematic with the latest deformation in the country rock.

Rast and Lutes (1979), and Lutes (1979) proposed a division of the southwestern part of the batholith into a western, and a probably younger eastern part based on lineaments from satellite photographs and magnetic intensity data of McGrath (1970). Pressure-temperature conditions of 500 to 550°C and 2 to 3 Kb were suggested from metamorphic mineral assemblages in the contact aureole. The subdivisions were named the "Skiff Lake Granite" in the west and the "Hawkshaw Granite" in the east, consisting respectively of grey porphyritic, muscovite-biotite granite and pink porphyritic, biotite granite.

Work by Venugopal (1979) outlined the extent of the "granodiorite" first recognized by Rutledge (1957) along the western side of the batholith. Venugopal's petrographic work showed this body to be essentially a hornblende-biotite tonalite and the name "Hartfield Tonalite" was introduced. He observed the parallelism of schistosity in the country rock with the foliation in the tonalite noted by O'Brien (1977) and similarly invoked a syntectonic origin for the intrusion. In considering the contact relationships with the Hawkshaw Granite, Venugopal noted that the "Hawkshaw Granite appears to cross the trend of the tonalite" west of the Nackawic River. Petrographic work by Lutes (1981) revealed syn- to post-tectonic relationships in the composite contact aureoles of the Skiff Lake and Hawkshaw granites and found a later growth of cordierite and andalusite in the latter suggesting a younger age for the Hawkshaw Granite.

A number of K-Ar ages have been determined on biotites from various parts of the batholith. K-Ar ages of 312 and 378 Ma were obtained by Lowden (1962, 1963). A K-Ar date of 400 Ma was reported by Faul et al. (1963) from porphyritic rocks of the Skiff Lake Granite near Danforth in Maine, and K-Ar dates of 362 ± 16 Ma and 348 ± 16 Ma were reported by Poole (1972) for rocks of the Hawkshaw Granite near Hawkshaw. A Rb-Sr whole rock isochron reported by McCutcheon et al. (1981) suggests an age of 389 ± 20 Ma for the batholith. A lamprophyre dyke intrudes Silurian greywackes south of Prince William and has been dated at 358 ± 18 Ma (Les Fyffe, pers. comm.).

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PHYSIOGRAPHY

The Pokiok Batholith underlies areas of low relief and gently rolling topography. Hills are pronounced along the margins of and, in places, within the batholith. These elevations rarely exceed 300 metres, and are underlain by hornfelsic country rock that is more resistant to weathering and erosion than granite.

The southwestern part of the batholith is in the St. Croix River watershed, while the eastern part is drained to the north by the Saint John River and its tributaries, and to the south by the Magaguadavic River.

The trend of glacial striae indicates a generally south-eastward direction of glaciation. Topographic lineaments and stream patterns in the southern half of the batholith reflect this dominant direction of glaciation.

The surficial geology of the area is included in reports by Hamilton and Carroll (1975), Finamore (1981), Rampton and Paradis (1981), Seaman (1981, 1982), and Hunter and Lavergne (1982). Extensive glacial drift covering the batholith mainly consists of ablation till with minor glaciofluvial and outwash deposits. Proglacial deposits occur along the banks of the Saint John River.

REGIONAL GEOLOGICAL SETTING

The Pokiok Batholith separates two tectonostratigraphic zones: the Miramichi, and Magaguadavic - St. Croix zones (Ruitenberg et al. 1977; Fyffe et al. 1981). The Miramichi Zone, which lies north of the batholith, contains a thick basal unit of quartzite, quartz wacke, and slate that is overlain by a series of felsic and mafic volcanics, greywacke, and slate. These rocks range from Cambrian (?) to Middle Ordovician age and were polydeformed and regionally metamorphosed during the Taconian Orogeny. Sedimentary and volcanic rocks of Silurian (?) to Lower Devonian age unconformably overlie this sequence and were deformed with the older strata during the Acadian Orogeny.

The Magaguadavic-St. Croix Zone, which occurs south of the batholith, comprises a thick sequence of turbidites of Wenlockian to Ludlovian age (McKerrow and Ziegler 1971) that was deformed during the Acadian Orogeny. The Pokiok Batholith intrudes the faulted boundary between these tectonostratigraphic zones and its elongate shape (Figure 1, Plates 80-101(R), 102(R)) is to a large extent controlled by this boundary.

The metamorphic aureole of the Pokiok Batholith is more extensive along the northwestern than the southeastern margin. Geological mapping along the northwestern margin of the batholith has indicated extensive thermal metamorphism in the contact aureole, producing assemblages of cordierite-andalusite and sillimanite (Venugopal 1979; Lutes 1979). This is accounted for by a shallow dip of about 45° for the granite contact in the Canterbury area (Rast and Lutes 1979).

Petrofabric studies by Lutes (1981) have shown that part of this metamorphic episode was syntectonic with the Acadian cleavage that generally parallels the granite contact. Although little detailed work has been done along the southeastern margin of the batholith, thermal metamorphism here is apparently restricted to a narrow zone along the granite contact (Anderson and Poole 1959) except in the vicinity of Crabbe Mountain (O'Brien 1977).

O'Brien (1977) recognized block-faulting as a major structural control along the northwestern margin of the batholith. The spatial distribution of Cambrian-Ordovician and Silurian-Devonian rocks along the granite contact reflects horst and graben development, which in its earliest stages influenced the deposition of Silurian-Devonian strata (Venugopal 1979). Later vertical movements along some of these faults exposed part of the batholith within a horst bound by the northeast-trending Temperance Vale and Hainesville faults (O'Brien 1977). Recent mapping has delineated a major fault, the Magaguadavic Lake Fault, that can be traced from Magaguadavic Lake northward through Nackawic to Pinder and along the western margin of the batholith north of Millville (Figure 1).

DESCRIPTION OF MAP UNITS

The Early Devonian Pokiok Batholith (Martin 1970) was previously subdivided into three rock units based on petrography, structure, magnetic susceptibility, and intrusive relationships. These are in chronological succession: the Hartfield Tonalite (Venugopal 1979), the Skiff Lake Granite and the Hawkshaw Granite (Lutes 1979). The current investigation concurs with this subdivision, but has further subdivided the Hawkshaw and Skiff Lake granites (Figure 1). The plutonic rocks in this study are classified according to the I.U.G.S. classification of igneous rocks (Streckeisen 1973).

HARTFIELD TONALITE (Unit Ht)

The Hartfield Tonalite (Venugopal 1979) is located along the western margin of the Pokiok Batholith where it extends from south of the Saint John River northward as far as Temperance Vale, occupying an area of about 50 km^2. It is well exposed in low-lying glaciated outcrops in fields and along roads in the vicinity of Campbell Settlement. In addition, there are outcrops exposed along the Trans-Canada Highway and the access road to Ingraham Lake south of the Saint John River. A body of similar rocks occurs 13 km to the northeast of Temperance Vale, and is well exposed in the stream bed of the Keswick River.

The Hartfield Tonalite ranges in composition from a grey, coarse-grained, hornblende-biotite tonalite to quartz diorite. It weathers to a buff-white colour and carries a distinct foliation that is defined by elongate biotite, hornblende, and plagioclase and shows a marked variation in attitude across the area. South of the Saint John River this foliation trends approximately east-west, parallel to the intrusive contact of the unit, and dips in a southerly direction from 45° to 70° (Figure 2). Near Campbell Settlement, the foliation is vertical

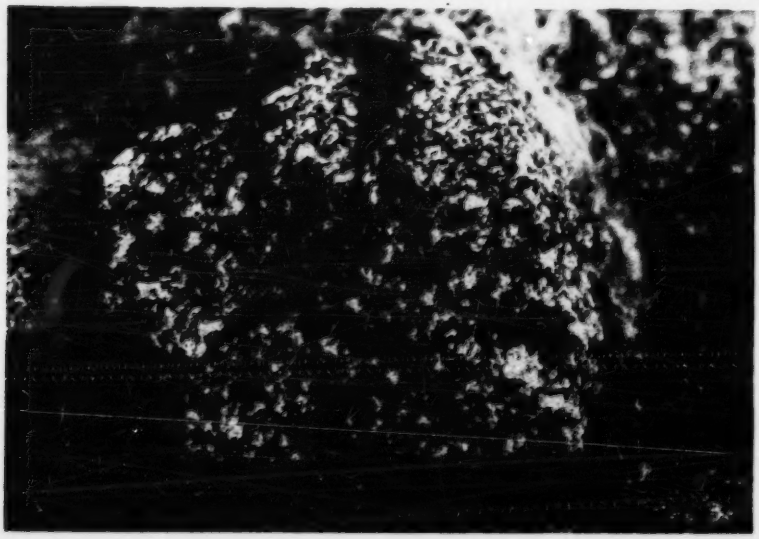

FIGURE 2. Hartfield Tonalite on Trans-Canada Highway looking east. Foliation strikes east-west and dips to south.

and trends approximately northeast; from Buttermilk Creek to Temperance Vale, it trends more easterly and is subvertical. A distinct foliation in the Hartfield Tonalite on the West Keswick River strikes about east-west and dips nearly vertical. Locally a cataclastic fabric is present and is rarely crenulated. In places on the Keswick River, the younger granitic rocks surrounding the Hartfield Tonalite have a weak foliation that strikes approximately east-west.

The Hartfield Tonalite is composed mainly of plagioclase, quartz, biotite, hornblende, and alkali feldspar with minor amounts of sphene, epidote, zircon, tourmaline, allanite, and opaque minerals. Petrographic analysis by Rutledge (1957) of three samples taken south of the Saint John River yielded average percentages of the major constituents as follows: oligoclase-andesine (58%), quartz (21%), alkali feldspar (2%), biotite (18%), and accessory minerals (1%). Venugopal (1979) estimated mineral percentages for the Hartfield Tonalite as follows: plagioclase (50-60%), quartz (15-18%), alkali feldspar (1-5%), hornblende (2-5%), biotite (10-15%), sphene (1-2%), and epidote (1-2%). Stained slabs of rocks from this unit 2 km east of Campbell Settlement contain less than 0.5% alkali feldspar whereas samples from outcrop along the Trans-Canada Highway, near the intrusive contact with the Hawkshaw Granite, contain about 5% alkali feldspar. A sample from the Keswick River contains about 5 to 7% alkali feldspar. It would appear that the Hartfield Tonalite is enriched in alkali feldspar in areas near the contact with the Hawkshaw Granite.

Thin sections revealed that plagioclase exhibits oscillatory zoning and is often partially saussuritized. Crystals are commonly fractured and annealed, and quartz is strained. Biotites are fresh and unaltered, but in places are bent or kinked and show undulatory extinction. Hornblende is yellow-green, pleochroic, and commonly euhedral. Alkali feldspars are generally small, untwinned, and anhedral. Sphene is generally euhedral to subhedral, and occurs as inclusions in biotite or as large grains in the groundmass.

Xenoliths and megaxenoliths of biotite schist are common in the Hartfield Tonalite south of the Saint John River. They vary in length up to one km and parallel the foliation in the tonalite and the intrusive contacts with the country rock.

The Hartfield Tonalite is intruded by a number of small stocks of pink biotite granite (Unit Heb) that is lithologically similar to part of the Hawkshaw Granite. The intrusive contacts are sharp, but both the granite and the tonalite have a foliation. If this foliation is of Acadian age, these rocks were intruded during this deformation. A number of garnetiferous aplitic and leucogranitic dykes intrude the western margin of the Hartfield Tonalite from Temperance Vale to Campbell Settlement and near Ingraham Lake.

SKIFF LAKE GRANITE

The Skiff Lake Granite (Lutes 1979) is located in the southwestern part of the Pokiok Batholith and occupies 500 km^2. It is divided into five map units based on consistent mappable variations in texture, i.e., porphyritic (hiatal, seriate) or equigranular, and mineralogy (muscovite- and/or biotite-bearing). These are: porphyritic, muscovite-biotite granite (Unit Spm); equigranular, biotite granodiorite (Unit Seg); porphyritic, biotite granodiorite (Unit Spb); equigranular, biotite granite (Unit Seb); and equigranular, muscovite-biotite granite (Unit Sem).

Porphyritic Muscovite-Biotite Granite (Unit Spm):

This unit constitutes approximately 60% of the total area of the Skiff Lake Granite. Exposures are found along numerous logging roads between Skiff Lake and Fosterville. The largest outcrops are located on and around Skiff Lake and Second Eel Lake where the granite commonly forms small islands. Unit Spm consists of grey, coarse-grained, seriate (megacrystic), muscovite-biotite granite. Grain size and texture are homogenous and the granite shows no evidence of chilling against xenoliths or country rock.

Unit Spm contains abundant xenoliths and megaxenoliths of mica schist and hornfels in its northern part between Skiff Lake and Fosterville. These are highly metamorphosed and commonly contain andalusite and sillimanite. Xenoliths and megaxenoliths are usually aligned subparallel to the granite contacts with the country rock. Many xenoliths were observed to have diffuse haloes of biotite-enriched material grading into the granite. These are probably restite remnants. A lack of chilling of the granite against xenoliths or country rock suggests that it cooled relatively slowly in thermal equilibrium with its sedimentary envelope.

Phenocrysts in the granite are generally 3 to 5 cm long and commonly have a preferred dimensional orientation parallel to the granite contacts (Figure 3). The alkali feldspars are generally buff-white and are rarely pinkish. They are, therefore, virtually indistinguishable from the buff-white plagioclase except where differential weathering of glacially polished outcrops has produced brownish argillic alteration products after plagioclase, in contrast with buff-white alteration products after the alkali feldspars (Figure 4). Less than 5% of the phenocrysts are plagioclase.

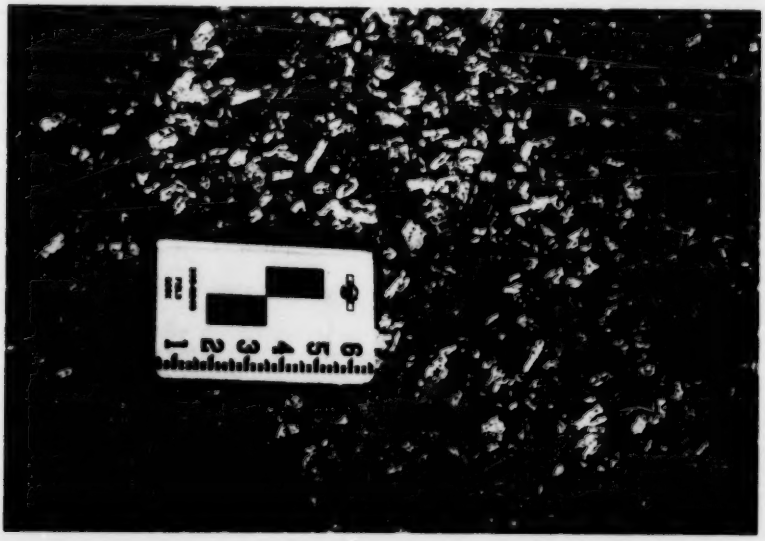

FIGURE 3. Grey porphyritic muscovite-biotite granite (Unit Spm) near Sample Location 15, Plate 80-102(R). Phenocrysts are flow aligned at 110°.

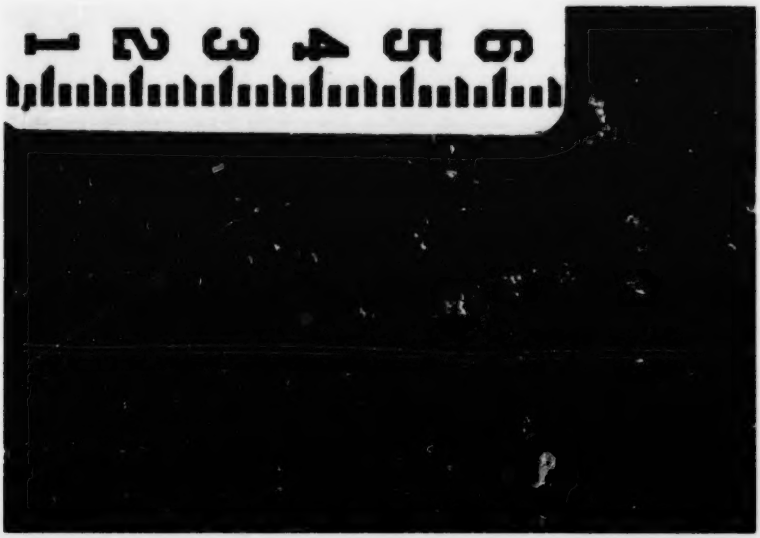

FIGURE 4. Unit Spm near Sample Location 13, Plate 80-102(R). Differential weathering contrasts white alkali feldspar and brownish plagioclase.

Stained slabs of Unit Spm show that alkali feldspar is more abundant than plagioclase. Total feldspar constitutes 65-70% of the the combined phenocryst and groundmass populations, and consists of 55% alkali feldspar and 45% plagioclase. Other minerals are quartz (25-30%), biotite (5%), and muscovite (1%). Accessory minerals are sphene, zircon, apatite, epidote, chlorite, and opaques.

Phenocrysts of alkali feldspar are microperthitic and contain inclusions of plagioclase, quartz, biotite, and muscovite. Gridiron twinning in these phenocrysts is usually poorly developed or absent, and simple Carlsbad twins are common. The mineral inclusions in the phenocrysts are smaller than similar mineral species in the groundmass. This indicates that nucleation of the alkali feldspar phenocrysts began relatively early in the crystallization of the granite. External grain boundaries of these phenocrysts surround and partially envelop groundmass minerals. Alkali feldspar in the groundmass is microperthitic and shows gridiron twinning characteristic of microcline.

Oligoclase-andesine exhibits oscillatory zoning, is anhedral to subhedral, and commonly contains small inclusions of biotite, muscovite, and plagioclase. The cores of plagioclase grains are commonly mildly altered to aggregates of sericite $\pm$ calcite $\pm$ epidote.

Biotite is pleochroic in shades of yellow and brown, and commonly contains inclusions of zircon and apatite. In places, biotite is altered to chlorite and sphene. Small grains of muscovite occur in accessory amounts in the groundmass of the rock. Some of these are intergrown with biotite and may be primary. Most of the muscovite in the rock is spatially associated with, and fills fractures in alkali feldspar. This muscovite is a product of secondary alteration of the alkali feldspar.

Aplite and pegmatite veins are quite common in Unit Spm. These are muscovite-rich rocks that generally contain black tourmaline (schorl) and pink garnet (almandine). Quartz and buff-white alkali feldspar are the major constituents and form granophyric intergrowths in the pegmatitic rocks.

Unit Spm is intruded by Units Spb, Seb, Sem, and Hpg. Unit Seg also appears to intrude Unit Spm but the contact relationship was not observed.

Equigranular Biotite Granodiorite (Unit Seg):

This unit crops out in the western part of the Skiff Lake Granite and constitutes about 10% of the intrusion. The few exposures of Unit Seg along the road between Fosterville and Forest City, consist of grey medium- to coarse-grained, equigranular to seriate, biotite granodiorite, locally containing muscovite. The lack of distinct phenocrysts is the criterion for distinguishing Units Seg and Spm.

Metasedimentary xenoliths and megaxenoliths of mica schist and hornfels are common within Unit Seg. Schistosity generally trends northward parallel to the western contact of the Skiff Lake Granite. The contact relationships between the xenoliths and Unit Seg are similar to those noted for Unit Spm. Infrequently, pegmatite dykes intrude matasedimentary xenoliths. Numerous granite veinlets and granitic "sweats" have developed along the schistosity.

Stained slabs indicate that plagioclase constitutes approximately 75% of the total feldspar (alkali feldspar - 25%) in Unit Seg. The total mineralogy consists of plagioclase (45-55%), quartz (30-35%), alkali feldspar (10%), biotite (7-10%), and muscovite (less than 1%). Accessory minerals are apatite, chlorite, zircon, sphene, and opaques.

Oligoclase-andesine varies in length to 3 cm in subporphyritic rocks and exhibits oscillatory zoning. Small biotite, quartz, and plagioclase inclusions are common. Many plagioclase grains have their cores altered to sericite + calcite. Alkali feldspar is microperthitic with gridiron twinning characteristic of microcline. Microcline grains are anhedral and tend to occupy interstices between other minerals in the groundmass. Less commonly the microcline is euhedral and occurs as phenocrysts up to 3 cm long in seriate rocks. These phenocrysts contain inclusions of plagioclase, biotite, quartz, and muscovite. Myrmekite is only slightly developed at the grain boundaries between microcline and plagioclase. In some places, microcline is observed intergrown with quartz in a micrographic texture.

Muscovite, when present, is usually associated with alkali feldspar as discrete inclusions or as long, optically continuous sheafs filling fractures in it. It therefore appears to be secondary in origin. In the groundmass, muscovite is sparse and is commonly intergrown with biotite. Biotite is pleochroic in shades of yellow to brown and contains inclusions of apatite and zircon. Biotite is locally altered to chlorite $\pm$ sphene.

Contact relationships with other units are not exposed but Unit Seg is assumed to intrude Unit Spm and to be intruded by Unit Sem.

Porphyritic Biotite Granodiorite (Unit Spb):

Unit Spb is a minor phase and constitutes less than one per cent of the Skiff Lake intrusion. It forms small bodies of grey, fine- to medium-grained, seriate, biotite granodiorite. Two bodies intrude Unit Spm north and west of Third Eel Lake and are about 0.25 to 0.5 km^2 in size. A third body is located near the centre of Unit Seb east of Bolton Lake. It occupies an area of 5 km^2 and is well exposed along logging roads.

The contact of the northernmost body of Unit Spb is exposed in a stream bed on its eastern margin. Here, the contact is gradational over 1 to 2 m with grey, coarse-grained, seriate, muscovite-biotite granite of Unit Spm. There are no xenoliths to indicate relative age relationships, but the close similarity in bulk mineralogical and chemical composition and the gradational nature of the exposed contact suggests little age difference between these intrusions. Unit Spb has no associated pegmatite or aplite, indicating that it was a relatively dry magma.

The second body of Unit Spb is defined by two outcrops 2 km southeast of Second Eel Lake. It is petrologically similar to the northernmost body. Although no contacts are exposed, one of the outcrops contains a small round xenolith of coarse-grained, porphyritic, muscovite-biotite granite of Unit Spm (Figure 5). This is evidence for a relatively younger age of intrusion of Unit Spb.

The contact of the large southernmost body of Unit Spb is exposed in two locations along its eastern border where pink granite of Unit Seb is intermingled with, and forms diffuse elongate xenoliths within the granodiorite of Unit Spb (Figure 6). These xenoliths are oriented parallel to the contacts of Unit Spb. Locally, on a scale of tens of centimetres, these two phases are intimately mixed and produce a hybrid granitoid rock. These relationships suggest that Unit Spb was intruded later than Unit Seb in this area and indicate that Unit Seb was not entirely crystalline prior to the intrusion of Unit Spb.

FIGURE 5. Grey, fine-grained seriate biotite granodiorite (Unit Spb) containing a xenolith of Unit Spm south of Second Eel Lake, Plate 80-102(R).

Unit Spb contains 40-50% plagioclase, 15-20% alkali feldspar, 25-30% quartz, and 5-10% biotite. Accessory minerals are apatite, chlorite, sphene, muscovite, zircon, and epidote. Phenocrysts in Unit Spb can reach 3 cm in length and in the two

northernmost bodies, are flow aligned in an east-west direction (Figure 7). This direction is parallel to the schistosity in nearby xenoliths and megaxenoliths within Unit Spm. The phenocrysts are alkali feldspars; stained slabs show that these are locally overgrown by a narrow (1 mm) mantle of plagioclase feldspar.

The alkali feldspar is not perthitic and some grains show gridiron twinning indicative of microcline. Smaller grains are interstitial to other minerals in the groundmass and contain small inclusions of plagioclase, biotite, and quartz. Larger grains become poikilitic where they enclose the groundmass minerals. Myrmekite is often formed at grain boundaries between microcline and plagioclase. Laths of secondary muscovite locally replace alkali feldspar and some are intergrown with biotite.

Oligoclase-andesine exhibits oscillatory zoning and locally contains inclusions of quartz and rarely plagioclase and biotite. Plagioclase grains commonly have sericitized cores.

Biotite is yellow-brown pleochroic and shows a well-defined, preferred dimensional orientation. In places it is altered to chlorite + sphene, and has inclusions of apatite and zircon.

FIGURE 6. Schlieren of pink medium- to coarse-grained biotite granite (Unit Seb) in dark fine-grained granodiorite (Unit Spb) near Sample Location 81, Plate 80-102(R).

Equigranular Biotite Granite (Unit Seb):

Unit Seb forms two small intrusions exposed along logging roads in the southern part of the batholith. The intrusion east of Bolton Lake is about 30 km^2 in area and the one west of the lake, about 1 km^2. The granite is pink, equigranular, fine- to coarse-grained (Figure 8), and contains variable amounts of plagioclase (20-50%) and alkali feldspar (20-30%). Quartz constitutes about 30% and biotite, 5% of the rock. Accessory minerals include muscovite, chlorite, apatite, sphene, zircon, epidote, and opaque minerals.

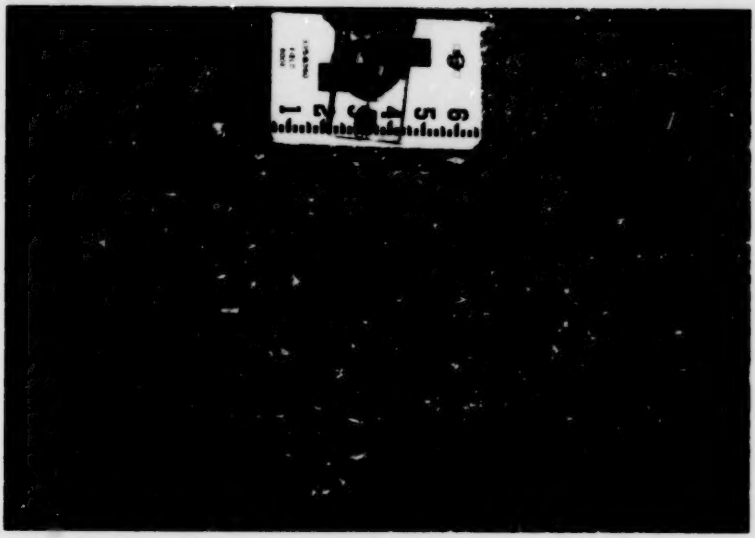

FIGURE 7. Grey, fine- to medium-grained seriate biotite granodiorite (Unit Spb) north of Third Eel Lake, Plate 80-102(R). Phenocrysts are flow aligned at 086°.

FIGURE 8. Pink, medium-grained equigranular biotite granite (Unit Seb) near Sample Location 81, Plate 80-102(R).

Alkali feldspar, which constitutes 33-50% of the feldspar, is perthitic and shows gridiron twinning characteristic of microcline. It contains abundant inclusions of biotite, quartz, and plagioclase and is partially replaced by muscovite along fractures. Poikilitic microclines are locally up to 1.5 cm in size giving the rock a seriate texture. Oligoclase-andesine exhibits normal and oscillatory zoning and commonly has an inner zone or core altered to sericite. Myrmekite occurs at grain boundaries between microcline and plagioclase.

Equigranular Muscovite-Biotite Granite (Unit Sem)

An intrusion of Unit Sem is located in the core of the Skiff Lake Granite and covers an area of about 100 km^2. It is generally well exposed along the main logging roads in the area. The granite is similar both mineralogically and chemically to Unit Hem located at Allandale.

The intrusive contact with Unit Spm is exposed in a series of outcrops about 5 km south of Second Eel Lake. It is transitional from medium-grained, equigranular to seriate, muscovite-bearing, biotite granite of Unit Sem through rocks of intermediate grain size that lack megacrysts, into coarse-grained, porphyritic granite of Unit Spm. The contact with Unit Seb is not exposed, but aeromagnetic contours in the vicinity suggest that it may intrude Unit Sem. The outcrop of Unit Seb on the western side of Unit Sem near Pirate Lake appears to be a small intrusion separated from the main body to the east.

Grey-coloured aplites and pegmatites are relatively common in this intrusion and have a similar mineralogy to the host rock. The pegmatites contain abundant muscovite. Small, 1 to 2 cm long, biotite-rich xenoliths are also common and presumably represent restite sedimentary remnants.

HAWKSHAW GRANITE

The Hawkshaw Granite (Lutes 1979) constitutes approximately 60% of the Pokiok Batholith. It extends from McAdam to the Nashwaak River and occupies an area of about 1000 km^2. The Hawkshaw Granite is composed of six map units that range from granodiorite to granite in composition. These are: equigranular biotite granite (Unit Heb); porphyritic granodiorite (Unit Hpg); porphyritic biotite granite (Unit Hpb); porphyritic muscovite-biotite granite (Unit Hpm); rapakivi granite (Unit Hpr); and equigranular muscovite-biotite granite (Unit Hem).

Equigranular Biotite Granite (Unit Heb)

This unit, located north of the Saint John River, occupies an area of approximately 300 km^2 and constitutes about 20% of the Hawkshaw Granite. The best exposures are along the Nackawic, Keswick, and West Keswick rivers. The largest intrusion of Unit Heb, extending 50 km northeastward from the Saint John River to a point 8 km southwest of Napadogan, generally consists of pink, fine- to coarse-grained, equigranular to locally seriate, biotite granite. The grain size and alkali feldspar/plagioclase ratios are variable and the rock is locally trans-granodioritic. Plagioclase constitutes about 30-40% of the rock; alkali feldspar, 20-30%; quartz, 25-35%; and biotite, 5%. The coarsest grain size is observed in Unit Heb in outcrops near Pinder adjacent to a body of Unit Hpb. This may indicate a gradational contact between the two units.

Several small mappable intrusions of Unit Heb occur within the Hartfield Tonalite in the vicinity of Campbell Settlement. These are about 1 km^2 in size and where exposed, their intrusive contacts are sharp. A foliation within these intrusions appears to be the same as that in the Hartfield Tonalite (Figure 9).

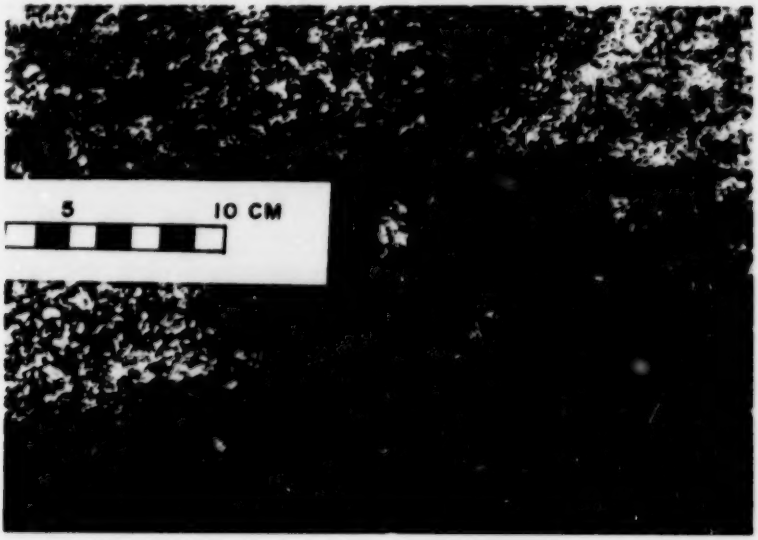

FIGURE 9. Contact between Unit Ht (to left) and Unit Heb (to right) near Campbell Settlement, Plate 80-101(R). Contact is sharp and trends approximately north-south. A foliation crosscuts both units and trends northeast.

A distinct tectonic foliation is present in the rocks of Unit Heb in the vicinity of the West Keswick River. This foliation is defined by oriented plagioclases and biotites and consistently trends about 115°. A large raft of Hartfield Tonalite, exposed along the West Keswick River, also carries this foliation and locally becomes mylonitic. Nearby, rocks of Unit Hpb are exposed in the stream bed of the river and are undeformed. The Hartfield Tonalite and Unit Heb were apparently deformed prior to the intrusion of Unit Hpb.

Porphyritic Biotite Granodiorite (Unit Hpg):

This unit, which constitutes 1 to 2 per cent of the total area of the Hawkshaw Granite, forms a border phase along the contact between the Skiff Lake and Hawkshaw granites. It consists of grey, coarse-grained, porphyritic to locally equigranular biotite granodiorite that is rarely muscovite-bearing. It generally contains small metasedimentary xenoliths and characteristically has small biotite-rich restite clots (Figure 10). The xenoliths contain pinitized grains of cordierite and radiating sheafs of fibrolitic sillimanite formed over biotites. The varying abundance and heterogeneous distribution of biotite in the granodiorite probably indicates that it is the restite remnant of sedimentary material. Plagioclase generally constitutes 40-50% of the rock; quartz, 35-40%; biotite, 10-15%; and alkali feldspar, 1-10%. Accessory minerals are muscovite, chlorite, apatite, zircon, epidote, calcite, and sphene. Pegmatites and aplites are common, usually contain tourmaline and garnet, and are rich in muscovite.

Where the rock is porphyritic, feldspar phenocrysts are 3 to 5 cm long and generally have a preferred orientation parallel to the intrusive contacts of the unit. The alkali

FIGURE 10. Elongate xenoliths of blue-grey schistose metasedimentary rock in grey porphyritic biotite granodiorite (Unit Hpg) at Sample Location 64, Plate 80-102(R).

feldspars are generally buff-white and are virtually indistinguishable from the buff-white plagioclase feldspar. Stained slabs of Unit Hpg indicate that the phenocryst population is dominantly composed of plagioclase feldspar. The plagioclase phenocrysts are oligoclase-andesine and exhibit oscillatory zoning with cores altered to sericite. Alkali feldspar phenocrysts are perthitic and simply twinned. Locally the phenocryst population is dominated by alkali feldspar and the rock is granitic in composition (Sample Locations 65, 67). At these localities the granite is grey and very similar in appearance to Unit Spm of the Skiff Lake Granite.

Alkali feldspars in the groundmass are commonly untwinned and not perthitic. Myrmekite is commonly developed at grain boundaries between plagioclase and alkali feldspar. Plagioclase grains in the groundmass are unzoned or only slightly zoned. Biotite is locally altered to chlorite ± sphene. Muscovite usually occurs intergrown with and replacing biotite or as optically continuous growths occupying fractures in alkali feldspars, and therefore appears to be wholly secondary in origin.

Its contacts are not exposed, but the rock distribution and the generally well-developed preferred orientation of phenocrysts and xenoliths suggest that Unit Hpg truncates Unit Spm of the Skiff Lake Granite. Structural trends in Unit Hpg are coincident with those of Unit Hpb of the Hawkshaw Granite and imply a consanguinity of these intrusions.

Porphyritic Biotite Granite (Unit Hpb):

This unit encompasses about 70% of the Hawkshaw Granite and constitutes those rocks as described in Lutes (1979) and therein defined as the Hawkshaw Granite. Unit Hpb underlies a total

area of about 700 km^2 largely between McAdam in the south and Nackawic in the north. It also underlies most of the south-eastern lobe of the Pokiok Batholith that extends from the Saint John River to Zealand, and forms a separate intrusion in the northeastern lobe of the batholith east of Millville. The best exposures are in road cuts along the Trans-Canada Highway from Allandale to Hawkshaw. Most areas underlain by Unit Hpb are accessible via logging roads or rivers and are reasonably well exposed. Notable exceptions are areas surrounding the Pokiok River northwest of Lake George and the Mactaquac River southwest of Zealand, which have minimal relief and are very boggy. Large areas west of the Magaguadavic Lake also have minimal relief and are not easily accessible.

Unit Hpb is characteristically a pink, coarse-grained, hiatal porphyritic (megacrystic), biotite granite. It is locally medium-grained and shows little petrographical, textural, or colour variation. This homogeneity is consistent on both a local and a regional scale. The rocks of Unit Hpb typically contain 30-40% alkali feldspar phenocrysts, 30-40% plagioclase, 25% quartz, and 5% biotite with an estimated alkali feldspar/plagioclase ratio of 1:1. Accessory minerals include chlorite, muscovite, epidote, sphene, apatite, and zircon. Xenoliths of country rock are relatively rare throughout Unit Hpb. Small (1-2 cm) xenoliths of biotite-enriched material occur locally and may represent restite remnants of highly metamorphosed country rock depleted in quartzose and feldspathic material.

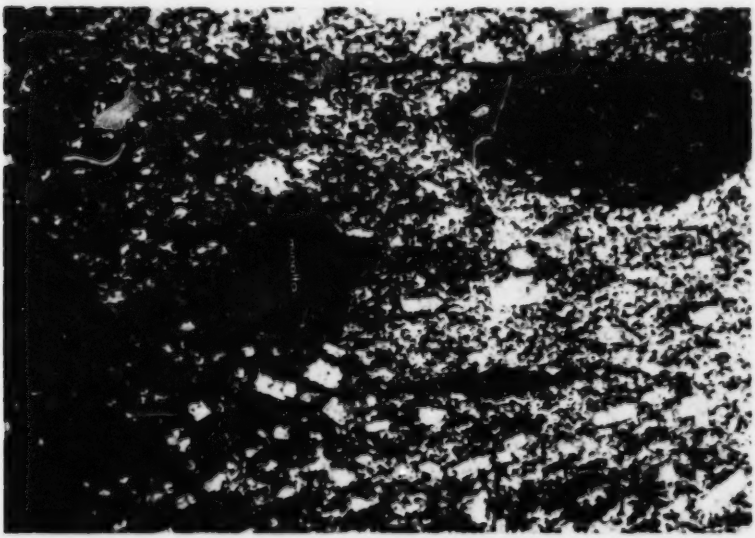

FIGURE 11. Pink, coarse-grained, porphyritic biotite granite (Unit Hpb) containing a mafic xenolith oriented parallel to flow-aligned alkali feldspar phenocrysts at 046° and parallel to the intrusive contact of the batholith located near Sample Location 23, Plate 80-102(R).

The pink alkali feldspar phenocrysts, which characterize this unit, are generally 3 to 5 cm long, euhedral, and noticeably perthitic in hand specimen. The phenocrysts commonly have

a preferred orientation with their long axes subparallel to the intrusive contacts of the unit (Figure 11). This preferred orientation is common to both phenocrysts and elongate metasedimentary xenoliths, is developed generally near the outer margins of the unit, and is best exposed in the areas south and east of Allandale and south of Fifth Lake.

The abundance of alkali feldspar phenocrysts in the rock generally varies from 15 to 50% and is locally as high as 60% in textural varieties that are glomeroporphyritic. The coarse-grained, hiatal (megacrystic) rocks constitute about 85 to 90% of Unit Hpb. Alkali feldspar generally accounts for less than 5% of the groundmass, being present wholly as phenocrysts. The phenocrysts generally show simple twinning, although microcline twins are fairly common. Perthitic exsolutions assume various shapes, most commonly strings, stringlets, beads, and patches (less often bands or flames). Patch perthites commonly exhibit polysynthetic twinning. The phenocrysts contain small inclusions of plagioclase, biotite, and quartz. In the groundmass, alkali feldspars typically show microcline twinning and occur interstitially to the other minerals. Large phenocrysts of alkali feldspar locally overgrow xenoliths in the granite, clearly indicating a relatively late stage of crystallization.

Oligoclase exhibits oscillatory zoning and is usually partially altered to sericite $\pm$ calcite $\pm$ epidote. Myrmekite is commonly developed at grain boundaries between plagioclase and alkali feldspar. Biotite is yellow to red-brown pleochroic, commonly contains small inclusions of apatite and zircon, and in places is altered to chlorite and epidote or chlorite and sphene.

Medium-grained granite accounts for about 10 to 15% of Unit Hpb. Phenocrysts in these rocks are generally 1 to 2 cm in diameter and the texture is seriate rather than hiatal. Pink megacrysts of alkali feldspar 3 to 5 cm in diameter are sparse. These rocks contain similar proportions of the major constituents and have an alkali feldspar/plagioclase ratio of about 0.75 to 1.0.

Contacts of Unit Hpb are exposed in several localities. Outcrops along the contact between Unit Hpb and the country rock are exposed west of Charlie Lake. They contain a hybridized mixture of grey, equigranular granite and sedimentary xenoliths in various states of disaggregation. The character of the granite is similar to that of Unit Hpg and may indicate a common origin by assimilation of metasedimentary country rock. Typical coarse-grained, pink, porphyritic granite of Unit Hpb is found 2 km to the north and 1 km to the south indicating that contact hybridization is localized.

The northwestern contact between Unit Hpb and the country rock north of the Saint John River is exposed along the Nackawic River near Temperance Vale and along the road leading north to Millville. Here, the contacts are sharp and the granite retains its pink colour. Assimilation of country rock at the intrusive contacts of Unit Hpb thus appears to be restricted to areas south of the Saint John River. This may indicate that deeper levels of the granite are exposed to the south, or that it was intruded into a hotter and/or more water-rich environment.

The eastern contact between Unit Hpb of the northeastern lobe and country rock is well exposed in a series of road cuts near Upper Hainesville. Typical pink, coarse-grained, porphyritic, biotite granite of this unit intrudes mica schists and

laminated metasiltstones. Less than 10 m from the intrusive contact, the granite loses its pink colour and becomes grey. The contact itself is sharp and no assimilation of country rock is apparent.

The contacts of the southeastern lobe of Unit Hpb with the country rock in the Zealand area are exposed along road cuts in several areas. The rock comprises a pink, coarse-grained, hiatal porphyritic granite that retains its pink colouration up to its intrusive contacts with the country rock in all localities. These contacts are sharp and no hybridization or assimilation of country rock occurs.

The contact between Unit Hpb and Unit Spm of the Skiff Lake Granite is exposed in two outcrops near the shore of Palfrey Lake. These outcrops consist wholly of olive green, massive vein quartz and suggest extensive hydrothermal activity associated with this contact. No traces of mineralization were found associated with the quartz veins.

The contacts between Unit Hpb and Unit Heb are exposed along the Shogomoc River near Allandale, and along the West Keswick River. On the Shogomoc River, the contact between these two units is indistinct whereas exposures along the Trans-Canada Highway to the east of the bridge show the rock to be typical of Unit Hpb but to vary considerably in grain size, texture, and phenocryst abundance as one approaches the contact area. Considering the homogeneity of Unit Hpb, its transformation into a series of heterogeneous rock types is believed to mark the contact between Unit Hpb and Unit Heb in this area. The character of these rock types is interpreted to represent marginal hybridization. In the West Keswick River area, Unit Hpb consists of fresh, pink, porphyritic megacrystic granite. Nearby outcrops of Unit Heb consist of a weakly deformed and foliated, medium-grained, pink, equigranular, biotite granite that is intruded by thick veins of pegmatite and leucogranite. Although the contact between these two rock units is not exposed, the weakly deformed rocks of Unit Heb can be assumed to pre-date the intrusion of Unit Hpb.

Porphyritic Muscovite-Biotite Granite (Unit Hpm):

This unit constitutes about 10% of the total exposed area of the Hawkshaw Granite and occupies a total area of about 100 km^2. It forms northeast-trending, elongate bodies generally located in the central parts of Unit Hpb. Outcrops of Unit Hpm are sparse and access to areas underlain by these rocks is poor. A semi-continuous section is well exposed in the stream bed of a small brook on the south side of the Saint John River and some good exposures occur on logging roads north of the Saint John River. Paucity of outcrops necessitated the mapping of large parts of Unit Hpm from aeromagnetic interpretation. The magnetic signature of these rocks is consistently less than 3100 gammas on the regional aeromagnetic maps.

The unit consists of pink, medium- to coarse-grained, porphyritic (megacrystic), muscovite-bearing, biotite granite that is texturally and petrologically very similar to Unit Hpb, but contains 1-2% muscovite. Slabbed samples of Unit Hpm show a seriate texture with 5-15% pink alkali feldspar phenocrysts ranging in length from 3 to 5 cm. The phenocrysts enclose fully developed plagioclase and biotite in the groundmass and are therefore late in the paragenesis. Small grains of alkali feldspar are anhedral and occur interstitially to biotite, plagioclase, and quartz. Alkali feldspar generally constitutes approximately 15-20% of the rock; quartz, 35-45%; plagioclase, 30-40%; biotite, 3-5%; and muscovite, less than 1%.

Contacts between Units Hpm and Hpb are exposed in a small stream flowing northward into the Saint John River immediately northwest of a Carboniferous outlier, and on a logging road 4 km north of Dumfries on the north side of the Saint John River. At the former locality, rocks of Unit Hpb southeast of the contact consist of pink, coarse-grained, porphyritic, megacrystic biotite granite. These pass northward into pink, medium-grained, porphyritic rocks of Unit Hpm containing about 1% muscovite. No sharp intrusive contacts were recognized at this locality. On the north side of the Saint John River, Unit Hpm consists of pink, coarse-grained, porphyritic, biotite granite containing accessory amounts of muscovite. Rocks of Unit Hpb, 1 to 2 km to the northwest, lack muscovite but are otherwise strikingly similar to the nearby rocks of Unit Hpm. This slight mineralogical variation suggests intergradational rather than sharp intrusive contacts.

Contacts between Unit Hpb and Unit Hpm have been mapped 3 km west of Cranberry Brook in the Magaguadavic Lake area. Outcrops of Unit Hpm contain abundant pink phenocrysts typical of the unit. Nearest the contact, Unit Hpm rocks are medium- to coarse-grained and contain rare scattered pink phenocrysts of alkali feldspar 3 to 4 cm long. The groundmass is buff, equigranular, and contains 1-2% muscovite. Where phenocrysts are absent these rocks are similar to the relatively younger muscovite-bearing Unit Hem. Nearby exposures of Unit Hpb are deformed and oxidized, locally containing secondary muscovite.

Pink, fine-grained aplite dykes occur within Unit Hpm on logging roads near Cranberry Brook (Sample Location 60) and near the Little Pokiok River (Sample Location 62). These dykes are located near the mapped contacts between Unit Hpm and Hpb. No pegmatoid dykes were found within this map unit.

Rapakivi Granite (Unit Hpr):

Minor rapakivi granite, located within Unit Heb south of Allandale near the Shogomoc River, appears to be dyke-like with a thickness of 10 to 15 m and a strike length of 1 to 2 km. The orientation of the dyke is subparallel to the aligned phenocrysts in both the rapakivi granite and Unit Hpb. The dyke consists of grey to pink, medium-grained, seriate biotite granite and is notably finer grained than Unit Hpb.

A large percentage of the pink alkali feldspar in Unit Hpr is overgrown by a white mantle of plagioclase (Figure 12). The contacts of the rapakivi granite are intergradational and hybridized with Unit Hpb over about a metre. Diffuse interstitial veinlets of pink alkali feldspar occur locally in this zone and, in places, xenoliths of rapakivi granite are found in surrounding granite.

Equigranular Muscovite-Biotite Granite (Unit Hem):

This unit forms four separate intrusions that occupy a total area of about 100 km^2 or 10% of the Hawkshaw Granite. The intrusions consist of grey, medium-grained, equigranular to seriate muscovite-biotite granite having a characteristic aeromagnetic signature of less than 3100 gammas.

Stained slabs contain 25-40% alkali feldspar, 15-30% plagioclase, 30-40% quartz, 1-3% biotite, and 0.5-1.0% muscovite. Accessory minerals are chlorite, sphene, apatite, and zircon. Alkali feldspar, which comprises 50-66% of the total feldspar in the rock, shows microcline twinning and is usually perthitic. Commonly microcline partially encloses or envelops the groundmass minerals and is therefore late in the paragenesis. Myrmekite is rarely developed at grain boundaries with plagioclase. Plagioclase feldspars commonly exhibit strong oscillatory zoning from about An_{34} to about An_{10} and commonly have

FIGURE 12. Pink alkali feldspar phenocrysts mantled by white plagioclase in medium-grained biotite granite (Unit Hpr), 1 km south of Sample Location 23, Plate 80-102(R).

an inner core altered to sericite. Biotite contains inclusions of zircon and apatite, and in places is altered to chlorite and sphene. Muscovite usually occurs as large inclusions or intergrowths within alkali feldspar or is intergrown with biotite. Texturally, muscovite appears to be of secondary origin.

The largest intrusion of Unit Hem is located south of the Saint John River within Unit Hpb of the Hawkshaw Granite in the Allandale area extending southward to Kilburn Lake. It covers an area of about 80 km^2 and is exposed on logging roads through the area. The contacts of this intrusion with rocks of Unit Hpb are well exposed in a continuous 75 m section in the north, 3 km east of Brown Lake. Grey to pink, medium- to coarse-grained, seriate muscovite-biotite granite of Unit Hem is observed at the southern end of the section (Figure 13). Near the contact with Unit Hpb to the north, rounded xenoliths of mafic to intermediate composition up to 0.5 m in size become abundant and at the contact, enclaves of pink, coarse-grained, hiatal biotite granite of Unit Hpb occur in a fine-grained hybrid granitoid rock. These relationships indicate that this body of Unit Hem intrudes Unit Hpb. The abundant xenoliths of mafic and intermediate rocks in the intrusion are believed to have been transported a considerable distance and derived from rocks formed at greater depths as no rocks of similar composition are seen within the batholith at the present erosional level.

The contact of Unit Hem with Unit Hpb is discontinuously exposed in a series of outcrops to the south, 3 to 4 km east of Shogomoc Lake. Here, Unit Hpb contains locally abundant xenoliths of mafic to intermediate composition. Outcrops at the contact appear to be hybrid and intergradational between the two units whereas exposures to the north are typical of the rocks of Unit Hem.

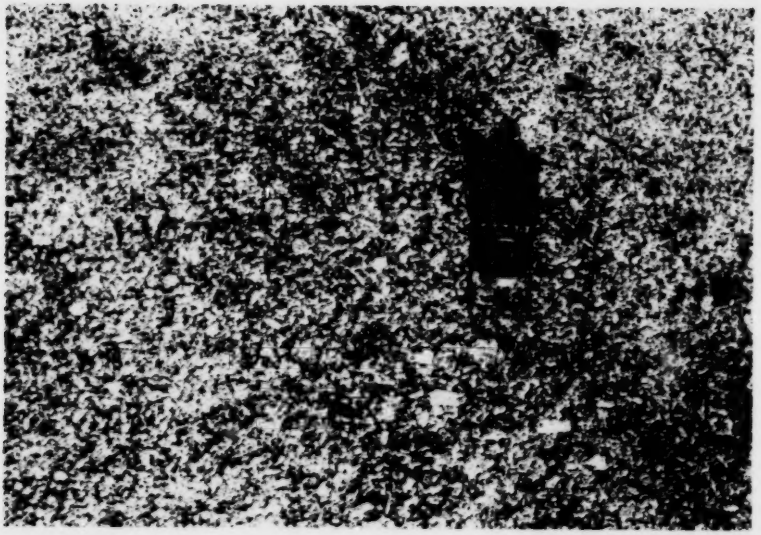

FIGURE 13. Grey, medium-grained seriate muscovite-biotite granite (Unit Hem) at Sample Location 37, Plate 80-102(R).

A small intrusion of Unit Hem is located in the southeastern lobe of the Pokiok Batholith east of Dumfries. It occupies an area of about 15 km^2 and is exposed along the main paved road on the north side of the Saint John River. Several small outcrops of this intrusion, south of the Saint John River 3 km east of Davidson Lake, are displaced relative to the main body suggesting a sinistral offset along a southeast-trending fault or series of faults. The granite exposed north of the Saint John River is generally a fine- to medium-grained equigranular rock. It is notably finer grained than other intrusions (1 to 2 mm as compared to about 5 mm), contains less biotite (0.0-1.0%) and more muscovite (1-3%). Exposures on the south side of the Saint John River are altered and appear greenish in hand specimen. Biotite in these rocks is largely altered to an assemblage of chlorite + epidote + sphene, plagioclase is partially sericitized, and alkali feldspar is intergrown with coarse secondary muscovite that appears to replace the feldspar along fractures.

The intrusive contacts are not exposed. The intrusion occupies the core of a body of Unit Hpm that in turn is surrounded by rocks of Unit Hpb. This zonal distribution may have been formed by a series of progressively more differentiated intrusions.

Another intrusion of Unit Hem is located 4 km north of Hawkshaw, along the margin of the Hawkshaw Granite north of the Saint John River. It underlies an area of about 15 km^2 and is exposed along the main paved road on the north side of the Saint John River and on access roads to the St. Anne Nackawic pulp mill. The outcrops along the Saint John River are typical lithotypes of the unit and contain muscovite-rich aplites and pegmatites. The two small exposures in the vicinity of the pulp mill, which are near a contact with rocks of Unit Hpb,

consist of grey to pink, fine- to medium-grained, equigranular granite. These rocks are slightly finer grained than those along the river and contain only accessory amounts of muscovite. The contacts of this intrusion are not exposed.

A fourth intrusion, near the tip of the northeastern lobe of the batholith, occupies an area of about 6 km^2. Good exposures are found along the Keswick River and along the road to Napadogan. They consist of pink, fine-grained, equigranular, muscovite-biotite granite containing 30-35% alkali feldspar, which is generally pink in colour, 30-35% plagioclase, 30% quartz, 5% biotite, and 1-5% muscovite. No contacts of this unit are exposed but it is inferred to intrude Unit Heb.

LEUCOGRANITE DYKES

A series of leucogranite dykes outcrop along the western contact of the Hartfield Tonalite, from the Nackawic River to Campbell Settlement (Venugopal 1979). They are also exposed at Upper Hainesville and 4 km south of Lower Caverhill where they intrude the margin of the Hawkshaw Granite. The dykes form swarms that are generally concordant with the prominent schistosity in the country rocks and can be found up to 500 m outside the intrusive margins of the granite and tonalite; relatively few dykes are found within the intrusive bodies. The dykes range in thickness from 0.5 to 50.0 m and tend to decrease in thickness and abundance away from the contact. Similar dykes are observed to intrude the Hawkshaw Granite near its margin just to the east of Coac Stream along the Saint John River. Minor scheelite occurs along joints and fractures in both granite and the leucogranite dykes at this location.

The dykes generally consist of grey, fine- to medium-grained aplites commonly accompanied by coarse crystalline pegmatites and granophyre. The rocks are characterized by long, thin sheets of biotite commonly 1 to 2 cm in length. Stained slabs clearly indicate that plagioclase/alkali feldspar ratios are highly variable, but quartz generally constitutes about 20 to 25% of the rock. Alkali feldspar commonly comprises from 20 to 40% of the rock, but locally the amount may be greater than 80%. Biotite constitutes 1-5% and some rocks contain 1-5% muscovite. These varieties are generally lacking biotite and locally contain visible pink garnets.

These leucogranite dykes would appear to represent a final phase of hydrous granitic magma in the batholith. The relatively widespread distribution of these hypabyssal dykes at the margins of the batholith north of the Saint John River suggests that the northern portion of the batholith crystallized later, and possibly at a higher crustal level, than the southern part.

CARBONIFEROUS ROCKS

An outlier of generally flat-lying, Carboniferous rocks overlies the eastern margin of the Pokiok Batholith at Upper Prince William on the south side of the Saint John River.

Ash-flow Tuff (Unit Ct):

A basal ash-flow tuff, from 5 to 15 m thick, directly overlies the granitic rocks of Unit Hpb on the south side of the Saint John River near Upper Prince William. Loose tuff blocks and rubble are seen on a steep slope above a small stream which exposes outcrop of Unit Hpb. Slabbed specimens of the tuff show well-developed compaction layering and contain elongate, flattened, pumice fragments several centimetres long.

Sandstone and Conglomerate (Unit Cs):
Grey and brown sandstone of the outlier were not included in the detailed mapping of the batholith and the contacts shown are duplicated after Anderson and Poole (1959). The contact of this outlier with Unit Ct is discontinuously exposed along a hillside to the west of Upper Prince William.

GEOCHEMISTRY

Selected rock samples from the Pokiok Batholith were analysed for major oxides and trace elements to define chemical variations within and the relative economic mineral potential of each of the granitic phases mapped. In addition, heavy mineral concentrates collected from stream sediments were tested as an exploration tool for tin, tungsten, and molybdenum mineralization by comparing them with samples from streams that drain known mineralized areas in the Sisson Brook area northeast of the Pokiok Batholith (Abbott and Tapley 1981).

PROCEDURES

Ninety-four samples were trimmed by hammer and submitted to X-Ray Assay Laboratories Limited in Don Mills, Ontario for analysis. Analytical methods used were: x-ray fluorescence for Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, CaO, TiO_2, MnO, Fe total (as Fe_2O_3), Rb, Sr, Zr, Ba, and Cr_2O_3; wet chemical methods for CO_2, H_2O+, H_2O-, F, and FeO; atomic absorption methods for Cu, Pb, Zn, Mo, and Li; neutron activation analysis for W, Ce, and Th; fire assay and neutron activation analysis for Au; delayed neutron counting for U; and emission spectroscopy for Sn. The precision of sample preparation and instrument stability as reported by X-Ray Assay Laboratories Limited is summarized in Table 1. Three samples were submitted in duplicate and are listed in Appendix I for comparison. Values of International Reference Standards reported by this laboratory are listed in Table 2 and are used as an estimate of accuracy.

Twenty-five additional samples were analysed by G. Gauthier and C. Brooks at the University of Montreal (see McCutcheon et al. 1981). Details of their analytical technique are described by Brooks (1980).

ANALYTICAL RESULTS

Major element and selected trace-element compositions of analysed rock samples from the Pokiok Batholith are given in Appendix I. The samples are grouped according to map unit and are numbered sequentially. The station locations of the samples are indicated by these numbers on Plates 80-101(R), 80-102(R).

Major Elements:
The means of the analyses for the major batholithic phases are presented in Table 3. The earlier phases of the Skiff Lake and Hawkshaw granites are geochemically very similar, with mean SiO_2 values ranging from 68.74 to 69.74%. The Hartfield Tonalite is distinctly more mafic in composition with a mean SiO_2 content of 62.70% whereas the late-stage equigranular muscovite-bearing granites (Units Sem and Hem) are distinctly more felsic in composition with a mean SiO_2 content of 72.12%. All of the batholithic phases are peraluminous, i.e., corundum-normative. Unit Hpg of the Hawkshaw Granite shows a markedly higher abundance of FeO, total iron, and TiO_2 relative to the other granites with equivalent mean SiO_2 content (Table 3) reflecting the higher percentages of biotite noted for this border phase located between the Skiff Lake and Hawkshaw granites. It is probable that the anomalously high biotite content of this unit is due to contamination by assimilation of biotite-rich country rock.

Silica variation diagrams for the major elements are presented in Figure 14. Many of the analytical results total as low as 98% and therefore they have been recalculated to 100% (anhydrous) to minimize the analytical errors. The samples from Units Sem and Hem form trends that are noticeably more fractionated than those for the other granitoid phases. Although Unit Hem on average contains slightly more CaO, MgO, TiO_2, and less Al_2O_3 than Unit Sem, both units are chemically very similar and show a normal fractionation trend of decreasing CaO, MgO, TiO_2, FeO, Fe^{total}, and Al_2O_3 and increasing K_2O, Na_2O, and P_2O_5 with increasing SiO_2 content.

Figure 15 is an AFM plot of samples from the plutonic granitoid phases plus the leucogranitic dykes marginal to the batholith. The samples define a linear trend near the alkali apex of the diagram. The samples from Units Sem and Hem group more closely together than those of the other plutonic units and are notably richer in alkalies.

TABLE 1

Reproducibility of sample preparation and instrument stability (data from X-Ray Assay Laboratories Limited)

Oxide	Mean (%)	S.D. (%)	Mean (%)	S.D. (%)
SiO_2	49.5	0.61	52.3	0.50
Al_2O_3	17.5	0.17	16.8	0.17
CaO	8.56	0.07	8.58	0.07
MgO	2.38	0.04	5.97	0.07
Na_2O	3.91	0.05	2.52	0.03
K_2O	0.64	0.01	0.78	0.01
Fe_2O_3	13.0	0.16	8.42	0.09
MnO	0.19	0.005	0.10	0.005
TiO_2	1.47	0.02	0.93	0.01
P_2O_5	0.14	0.005	0.11	0.005
L.O.I.	2.52	0.10	3.10	0.10

Note: Mean is the arithmetic mean.
Total iron reported as Fe_2O_3.
S.D. is standard deviation.
Statistics based on 42 replicate analyses.
L.O.I. is loss on ignition.

TABLE 2

Values on international reference standards
(data from X-Ray Assay Laboratories Limited)

SiO_2	59.9	59.3	38.6	60.0	69.5	52.5	5.72	65.5	39.0	71.2
	(60.09)	(59.68)	(39.24)	(59.72)	(69.19)	(52.72)	(6.01)	(65.2)	(38.39)	(69.96)
Al_2O_3	12.2	11.7	8.50	17.4	15.4	15.1	54.0	20.6	10.2	14.8
	(12.15)	(11.80)	(8.56)	(17.22)	(15.35)	(14.87)	(55.0)	(20.5)	(10.25)	(14.51)
CaO	7.87	8.05	14.5	4.99	2.02	10.9	0.38	2.20	13.7	2.55
	(8.00)	(8.26)	(14.72)	(5.00)	(1.98)	(10.98)	(0.29)	(2.14)	(13.87)	(2.45)
MgO	2.65	2.65	13.4	1.48	0.73	6.64	0.00	0.00	13.1	0.09
	(2.69)	(2.54)	(13.51)	(1.55)	(0.77)	(6.63)	(0.02)	(0.02)	(13.35)	(0.95)
Na_2O	4.23	4.21	0.73	4.30	4.16	2.35	0.05	6.27	2.98	3.53
	(4.35)	(4.15)	(0.71)	(4.31)	(4.06)	(2.15)	(0.00)	(6.2)	(3.07)	(3.55)
K_2O	4.36	4.13	0.25	2.87	4.45	0.69	0.11	5.20	1.38	4.11
	(4.51)	(4.24)	(0.18)	(2.93)	(4.52)	(0.64)	(0.00)	(5.20)	(1.41)	(4.03)
Fe_2O_3	6.31	6.42	17.8	6.78	2.77	11.4	5.77	0.17	12.9	2.79
	(6.29)	(6.44)	(17.79)	(6.88)	(2.62)	(11.10)	(5.8)	(0.065)	(12.94)	(2.83)
MnO	0.32	0.30	0.19	0.10	0.03	0.17	0.00	0.00	0.19	0.07
	(0.32)	(0.33)	(0.17)	(0.10)	(0.04)	(0.17)	(0.02)	(?)	(0.20)	(0.09)
TiO_2	0.15	0.15	3.84	1.07	0.50	1.08	2.66	0.03	2.74	0.38
	(0.15)	(0.15)	(3.75)	(1.06)	(0.50)	(1.07)	(2.78)	(0.01)	(2.61)	(0.38)
P_2O_5	0.45	0.53	0.07	0.52	0.15	0.14	0.07	0.03	1.09	0.13
	(0.44)	(0.54)	(0.07)	(0.50)	(0.14)	(0.14)	(0.08)	(0.02)	(1.06)	(0.12)

Note: ( ) are usable values as per Sydney Abbey, 1977. This represents only part of the 38 reference materials used for calibration of the whole rock analysis. Others are available on request.

Na_2O-K_2O-CaO contents of the samples are plotted in Figure 16. The samples define a broad linear trend parallel to the K_2O-CaO join. Samples from Units Sem and Hem group more closely together than those of the other plutonic units, are richer in K_2O and Na_2O, and define a trend that is slightly removed from other phases of the Hawkshaw and Skiff Lake granites. Samples from the Hartfield Tonalite are distinctly richer in CaO and form a trend from the CaO apex toward the Na_2O-K_2O join.

Trace Elements:

Trace-element concentrations of Zr and Ce are plotted against SiO_2 content in Figure 17. All granitoid units show a negative correlation with Zr. Samples from Unit Hpg of the Hawkshaw Granite are significantly richer in zircon (Table 3). Trends for Ce are less well defined, as data points tend to be slightly scattered. Samples from Unit Hpg are notably richer in Ce (Table 3). Other samples from the Hawkshaw Granite and the Skiff Lake Granite show a neutral or slightly positive correlation.

A plot of K_2O vs. Rb is shown in Figure 18. A well-defined positive correlation is shown for the granitoid rocks as a whole with individual phases tending to be clustered in separate groups. Samples from the Hartfield Tonalite have the highest K_2O/Rb ratio and those from Units Sem and Hem have the lowest K_2O/Rb ratio of the batholithic units. The dyke rocks show the greatest variation in K_2O/Rb ratios.

A plot of Sr vs. CaO is shown in Figure 19. A positive correlation is evident; CaO/Sr ratios are relatively constant with higher ratios noted for samples of the Hartfield Tonalite. Samples of the other batholithic phases tend to form elongate trends and those of the Hawkshaw Granite generally have slightly lower CaO/Sr ratios. Samples of the dyke rocks generally contain the lowest CaO/Sr ratio and show the greatest scatter.

A plot of Sr vs. Rb is shown in Figure 20. The samples tend to be clustered and a negative correlation is poorly defined. Samples from the muscovite-biotite granites (Units Sem and Hem) have the highest Rb/Sr ratio of the batholithic phases and samples from the Hartfield Tonalite have the lowest ratio. Samples from the Hawkshaw Granite generally contain a higher Rb/Sr ratio than the Skiff Lake Granite (except those of Units Sem and Hem). The dyke rocks generally contain low Sr (less than 75 ppm) and Rb (150-200 ppm).

The samples from the Pokiok Batholith were also analysed for Ba, U, Th, F, Li, Cu, Au, Mo, Sn, W, and Cr; these results are contained in Appendix I. Average analyses for Ba, U, Th, F, Li, and Cu in the batholithic phases are included in Table 3. Results for Au, Mo, Sn, W are generally low and near the limits of detection. It is notable that Units Hpb and Hpm contain the highest mean content of U, Th, and F of all the batholithic phases.

In summary, the data show distinct differences in the bulk composition of the granitoid rocks of the Pokiok Batholith with the Hartfield Tonalite being the most mafic and the muscovite-biotite granites of the Skiff Lake and Hawkshaw granites being the most felsic. Units Hpb and Hpm of the Hawkshaw Granite are slightly more felsic than the equivalent porphyritic phases of the Skiff Lake Granite (Units Spm, Spb, Seg; Table 3) and have the highest mean content of U, Th, and F of all the batholithic phases. The muscovite-biotite phases of the Skiff Lake Granite (Unit Sem) are chemically very similar to the muscovite-biotite phases of the Hawkshaw Granite (Unit Hem).

NORMATIVE MINERALOGY

The norms of the granitoid rocks were calculated according to the method of Irvine and Baragar (1971) and are included in Appendix I. Means of the normative minerals for the major batholithic phases are presented in Table 3. All of these contain normative corundum with the exception of two specimens from the Hartfield Tonalite, which contain normative diopside and hedenbergite. One specimen of Unit Sem and four specimens of Unit Hem contain normative rutile.

The rocks of the Pokiok Batholith plot close to the experimentally determined minima for low-pressure conditions (Figure 21) although allowance for normative An would indicate slightly higher pressures. A speculative estimate of about 3 kb is estimated by Lutes (1981) from metamorphic mineral assemblages in the northwestern contact aureole of the batholith.

TABLE 3

Average analyses and average norms of major batholithic phases

Map Unit	Htt		Spm, Spb, Seg		Sob, Hob	
	Mean	Range	Mean	Range	Mean	Range
SiO_2	62.70(4)	56.90-68.40	68.74(15)	66.90-71.00	68.38(8)	65.00-70.20
TiO_2	0.97(4)	0.56-1.67	0.54(15)	0.32-0.73	0.49(8)	0.24-0.81
Al_2O_3	15.75(4)	15.10-16.20	14.76(15)	13.50-15.50	15.19(8)	14.60-15.70
Fe_2O_3	1.82(4)	1.17-2.71	0.98(14)	0.59-2.10	1.92(5)	1.07-3.90
FeO	3.13(4)	2.00-5.20	2.39(14)	1.30-3.70	1.50(5)	1.00-2.40
MnO	0.09(4)	0.07-0.14	0.08(15)	0.06-0.10	0.08(6)	0.07-0.08
MgO	2.28(4)	1.23-3.88	1.10(15)	0.65-1.66	1.30(8)	0.78-2.01
CaO	4.22(4)	3.12-5.13	2.39(15)	1.82-3.12	2.60(8)	1.82-3.51
Na_2O	3.43(4)	3.00-3.79	3.08(15)	2.37-3.78	3.52(8)	3.32-4.03
K_2O	2.72(4)	2.60-2.93	3.65(15)	2.53-4.43	3.75(8)	2.36-4.52
P_2O_5	0.24(4)	0.16-0.39	0.20(15)	0.09-0.33	0.22(8)	0.17-0.28
Q	19.83		30.00		26.72	
C	0.07		1.92		1.15	
Or	16.52		22.04		22.40	
Ab	29.81		26.62		30.10	
An	19.90		10.78		11.59	
En	5.83		2.80		3.27	
Fs	2.89		2.90		0.51	
Mt	2.71		1.45		2.81	
Il	1.89		1.05		0.94	
Ap	0.57		0.48		0.52	
Rb	98(4)	60-180	172(15)	120-250	168(8)	50-220
Sr	223(4)	210-240	160(15)	120-200	162(80)	100-240
Zr	208(4)	170-270	206(15)	120-330	159(7)	110-240
Ba	363(4)	200-480	310(15)	200-650	321(7)	200-500
Ce	58(1)	-	72(14)	51-120	79(3)	63-93
U	2.9(4)	2.7-3.1	2.4(15)	1.8-3.8	3.0(7)	2.0-3.9
Th	14(1)	-	13(14)	7-22	13(4)	10-15
F	503(4)	420-600	504(15)	350-700	528(7)	360-640
Li	20(3)	17-23	-	-	44(2)	43-45
Cu	13(1)	-	17(15)	8-30	21(5)	12-28

TABLE 3 (continued)

Average analyses and average norms of major batholithic phases

Map	Hpg		Hqm, Hqb		Sem, Hsm	
Unit	Mean	Range	Mean	Range	Mean	Range
SiO_2	68. 8(8)	65.90-72.50	69.74(24)	67.30-72.90	72.12(21)	69.40-74.10
TiO_2	0.73(8)	0.39-0.94	0.46(24)	0.27-0.64	0.25(21)	0.06-0.46
Al_2O_3	14.60(8)	13.40-15.30	14.42(24)	13.50-15.50	14.67(21)	13.20-15.90
Fe_2O_3	1.08(8)	0.98-1.35	1.23(22)	0.61-2.01	0.98(9)	0.51-1.20
FeO	3.25(8)	1.50-4.20	1.34(22)	0.40-2.10	0.64(13)	0.20-2.10
MnO	0.07(8)	0.04-0.09	0.07(23)	0.04-0.09	0.06(21)	0.04-0.09
MgO	1.15(8)	0.63-1.48	0.77(24)	0.38-1.20	0.54(21)	0.22-1.37
CaO	2.29(8)	1.35-2.81	1.82(24)	0.63-2.63	1.42(21)	0.51-2.93
Na_2O	2.88(8)	1.99-3.39	3.30(24)	2.57-3.86	3.45(21)	2.41-4.28
K_2O	3.30(8)	1.81-4.00	4.36(24)	3.49-5.04	4.49(21)	1.92-6.24
P_2O_5	0.19(8)	0.06-0.28	0.17(24)	0.11-0.23	0.18(21)	0.10-0.33
Q	32.06		29.61		31.89	
C	2.63		1.41		2.01	
Or	19.83		26.38		26.86	
Ab	24.78		28.59		29.55	
An	10.29		8.11		5.94	
En	2.91		1.96		1.36	
Fs	4.07		0.83		0.07	
Mt	1.59		1.83		1.44	
Il	1.41		0.89		0.48	
Ap	0.45		0.41		0.42	
Rb	145	90-180	221(24)	140-290	245(21)	164-310
Sr	183	140-230	177(24)	80-240	105(21)	20-240
Zr	297	200-360	180(23)	80-250	105(21)	40-150
Ba	488	100-800	325(24)	50-600	226(21)	100-550
Ce	106	62-130	91(19)	61-130	62(19)	35-83
U	3.0	1.9-5.5	4.5(24)	2.4-6.6	4.1(4)	2.0-6.8
Th	18	11-22	18(21)	12-32	12(19)	7-19
F	563	290-1000	678(24)	420-960	509(20)	260-960
Li	-	-	36(3)	25-47	33(1)	-
Cu	14	4-25	8(22)	3-18	12(20)	3-27

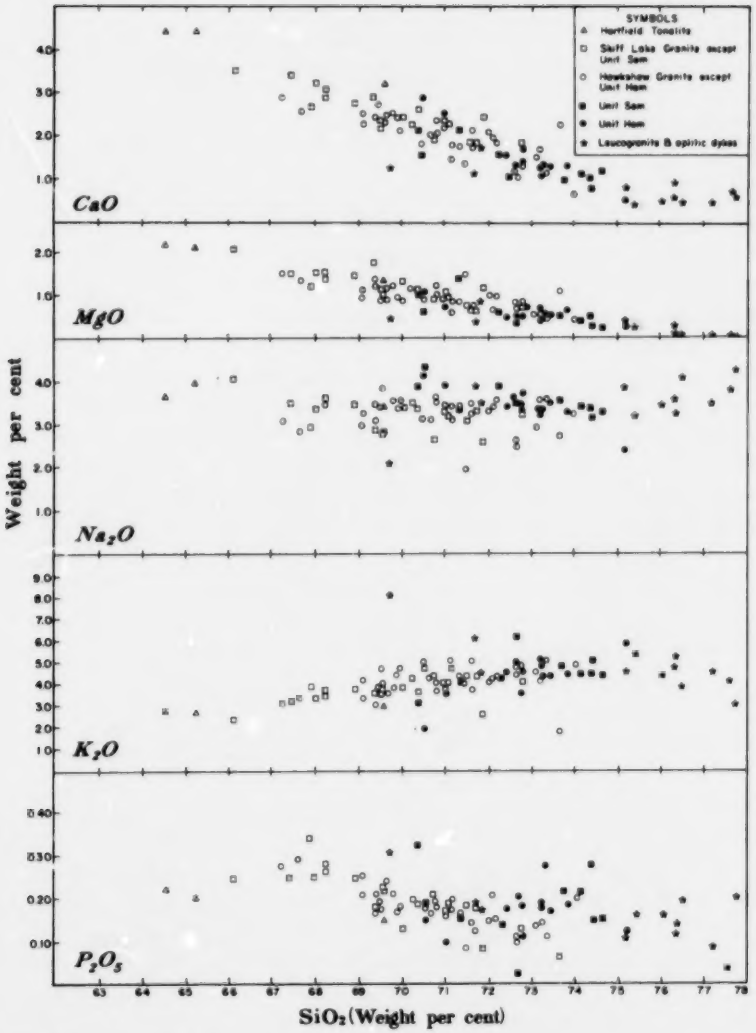

FIGURE 14. Silica variation diagrams.

ORIGIN OF POKIOK BATHOLITH

Considerable recent research into the nature of granitic rocks has contributed to concepts of their origin, emplacement, and fractionation. The concept of S-, I-, and A-type granites (Chappell and White 1974; Collins et al. 1982) has been widely used to categorize granites, especially with regard to their relative potential to host granophile mineral deposits. It is

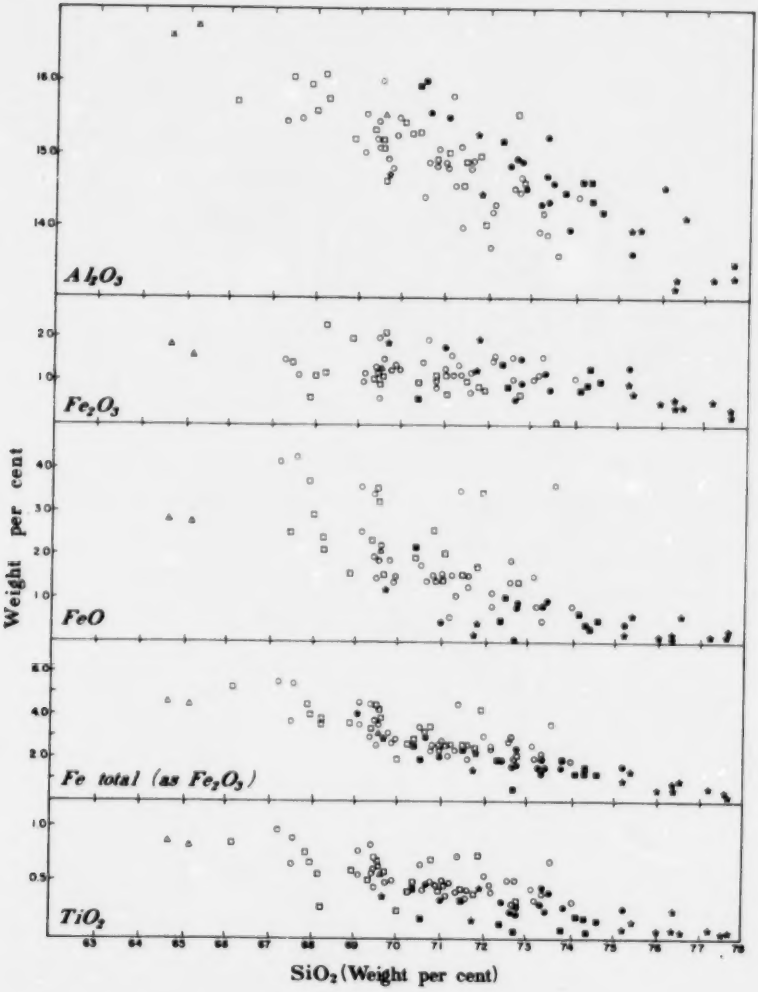

FIGURE 14 (cont'd). Silica variation diagrams.

generally thought that all tin mineralization is related to either S- or A-type granites; however, these concepts may have been extended beyond their original latitude in their ability to predict the occurrence of tin deposits. It is probably more important to recognize that tin-bearing granites have often evolved through a succession of associated granites that become more geochemically specialized with time.

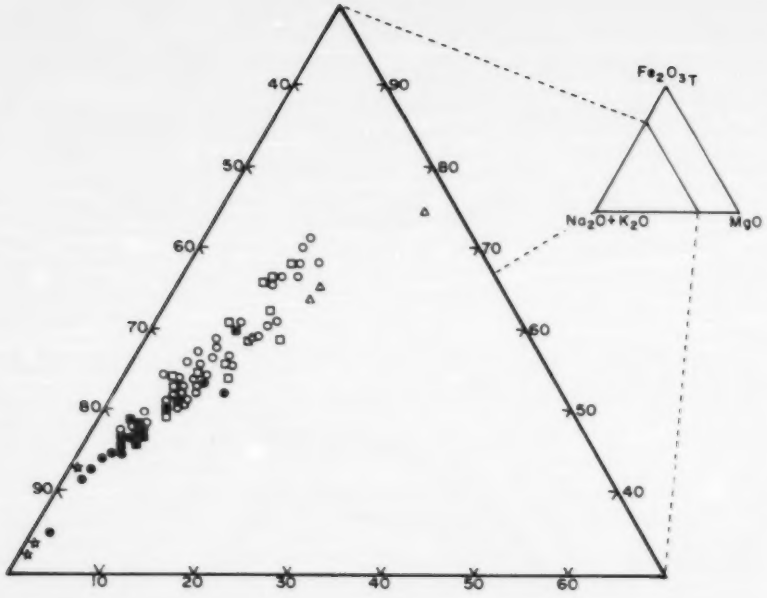

FIGURE 15. AFM variation diagram. See Figure 14 for symbols.

All of the granites of the Pokiok Batholith are strongly peraluminous, containing 1-3% normative corundum and are largely restricted in composition to relatively high SiO_2 types. These criteria are diagnostic of S-type granites. In addition, garnet and cordierite are known from the relatively common metasedimentary xenoliths in the batholith, hornblende is absent from most of the granites, biotite is the common ferromagnesian mineral and muscovite is relatively common in the more felsic varieties.

Some features of the Pokiok Batholith are more characteristic of I-type granites. The relatively high Na_2O in these rocks (generally greater than 3%) is anomalous in comparison to the values obtained from the Australian S-type granites at equivalent K_2O contents, and sphene is a relatively common accessory mineral. The Hartfield Tonalite is the most mafic of the major granitic plutons in the batholith and has many of the characteristics of an I-type granite with the exception that it is strongly peraluminous.

Initial Sr^{87}/Sr^{86} ratios are additional criteria in distinguishing between I- and S-type granites. Chappell and White (1974) recommend ratios of greater than 0.708 and in the range of 0.704-0.706 for S- and I-types respectively. Initial Sr^{87}/Sr^{86} ratios for rocks of the Pokiok Batholith are presented in McCutcheon et al. (1981). All data for the batholith yield a ratio of 0.7055±0.0007; however, an isochron obtained from the Skiff Lake granites had an initial Sr^{87}/Sr^{86} ratio of 0.7084±0.0011. These data are in a range which is not clearly either I- or S-type. It was noted by McCutcheon et al. (1981) that the Pokiok Batholith was very similar to the Criffell intrusions in Australia and may be the result of hybrid melting rather than simple anatectic melting of crustal material. It is evident that melting in the source region has involved igneous as well as sedimentary rocks, resulting in

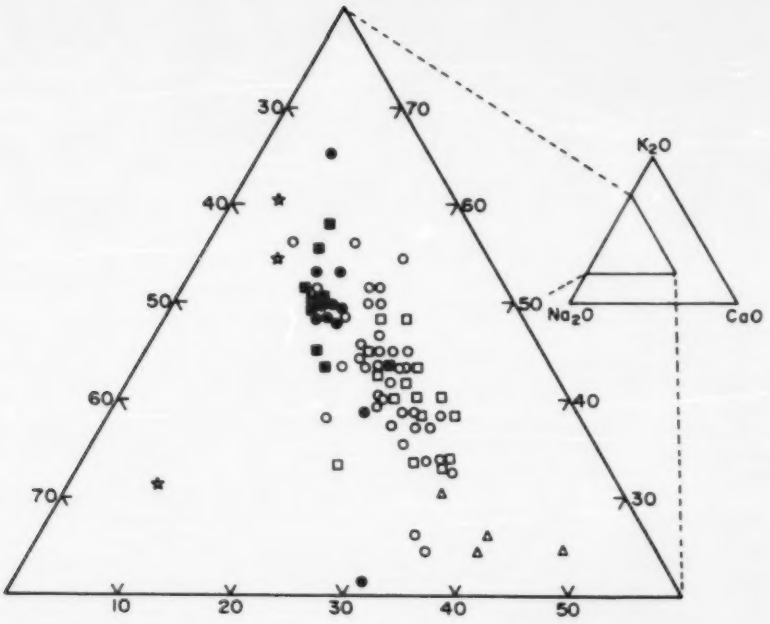

FIGURE 16. Alkali variation diagram. See Figure 14 for symbols.

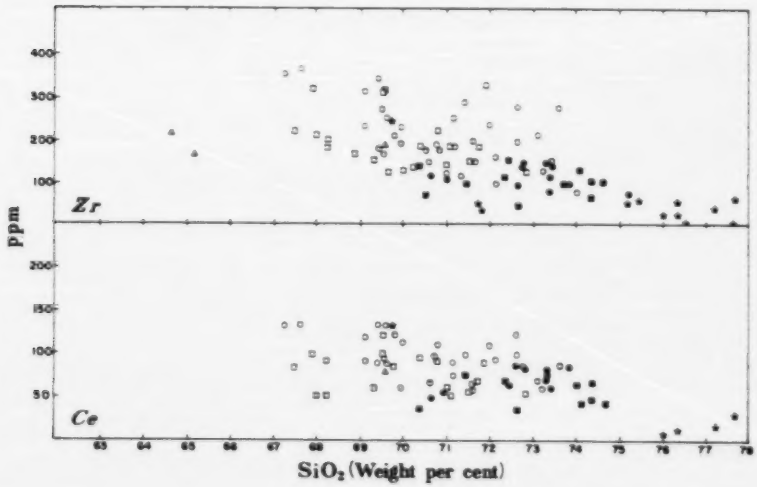

FIGURE 17. Variation of Zr and Ce versus SiO_2. See Figure 14 for symbols.

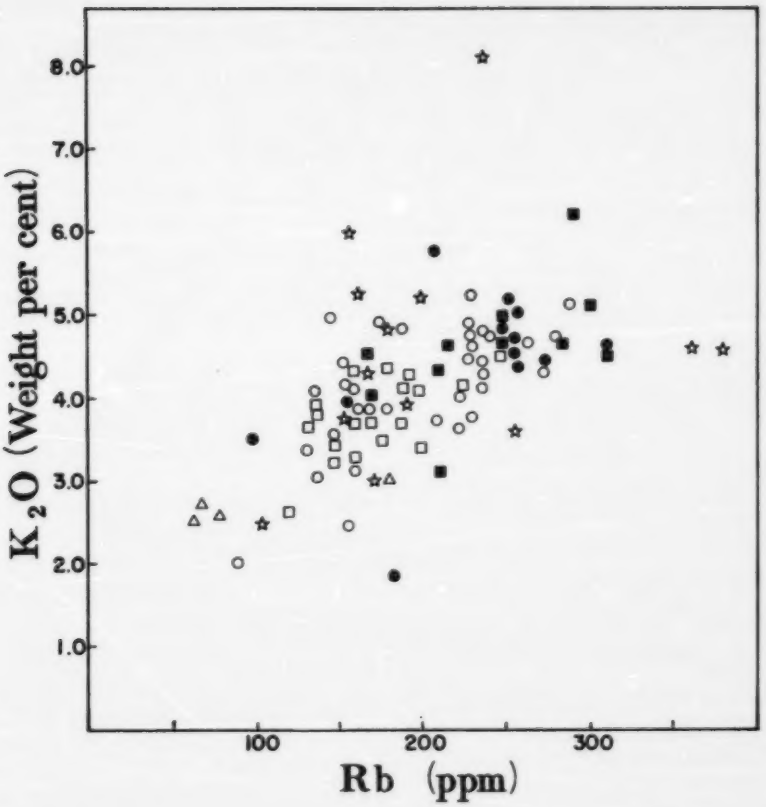

FIGURE 18. Variation of K_2O versus Rb. See Figure 14 for symbols.

a mixed I- and S-type character. A-type granites (Collins et al. 1982) are so called because they tend to be alkaline, anorogenic, and anhydrous. Chemically, they are distinguished from I-type granites by higher Nb, Ga, Y, and REE and lower Al, Mg, and Ca at equal SiO_2 contents. It is not apparent that any of the granites in the Pokiok Batholith fit this category.

Elemental concentrations of the granites are intermediate between the plumasitic and palingenic granites of Tauson and Kozlov (1973). Palingenic granites are interpreted to have formed by complete melting of metamorphic rocks in the earth's crust. Plumasitic leucocratic granites (tin granites), which contain high values of rubidium, fluorine, lithium, and beryllium and low values of strontium and barium, are interpreted as the latest acid differentiates of palingenic granites.

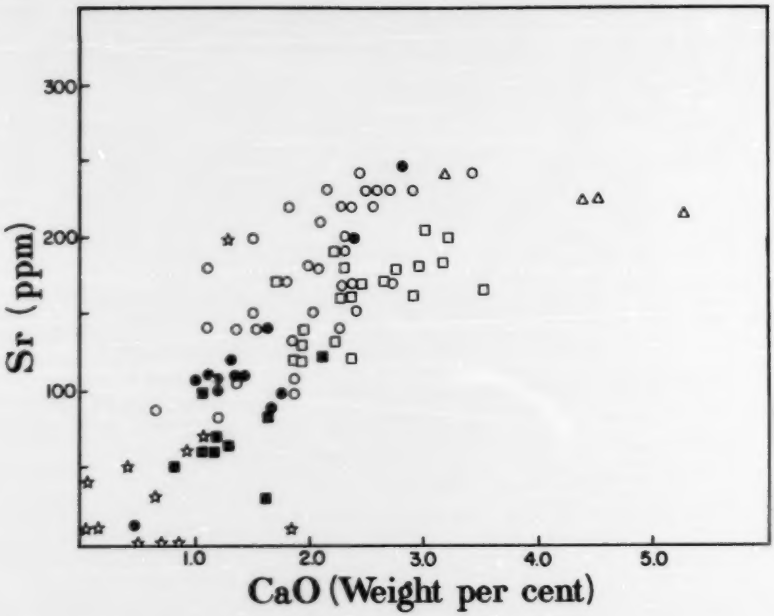

FIGURE 19. Variation of Sr versus Cao. See Figure 14 for symbols.

ECONOMIC GEOLOGY

A number of mineral occurrences are reported from the Pokiok Batholith. Molybdenite is found near the intrusive contact with quartzite and schist northwest of Springfield; in association with beryl near the intrusive contact west of Zealand (Anderson and Poole 1959); in association with wolframite in a quartz vein in granite near Dumfries (reported by Patterson 1957); and as minor disseminations along shear fractures in deformed granite on the north side of the Saint John River opposite Dumfries. Chalcopyrite occurs along the Coac Stream northwest of Dumfries, and along joint fractures in Units Sem and Seb in the core of the Skiff Lake Granite. Minor Pb-Zn sulphides occur in a narrow fault zone in the granite near Pinder. Robert Connors, a New Brunswick prospector, found minor base-metal sulphides and molybdenite in Unit Hem near the Magaguadavic Lake Fault southeast of Allandale.

Antimony has been mined since 1970 from a vein deposit in Silurian greywackes east of the Hawkshaw Granite near Lake George (Morrissy and Ruitenberg 1980). More recently, significant tungsten (scheelite) and uranium mineralization (mainly coffinite) has been discovered northwest of the antimony deposit. Scheelite occurs mainly in skarn (calc-silicate hornfels) underlain by granite at a depth of about 400 m. Scheelite-bearing quartz veins within this granite may indicate the existence of a younger underlying source. Scheelite has recently been discovered by Robert Connors in quartz veins in Silurian calc-silicate hornfels on the Coac Stream that is very similar to the occurrence at Lake George. The veins generally have a north-south or northwest strike. They occur in Unit Hpb and in leucogranite dykes, indicating a relatively young age for the mineralization.

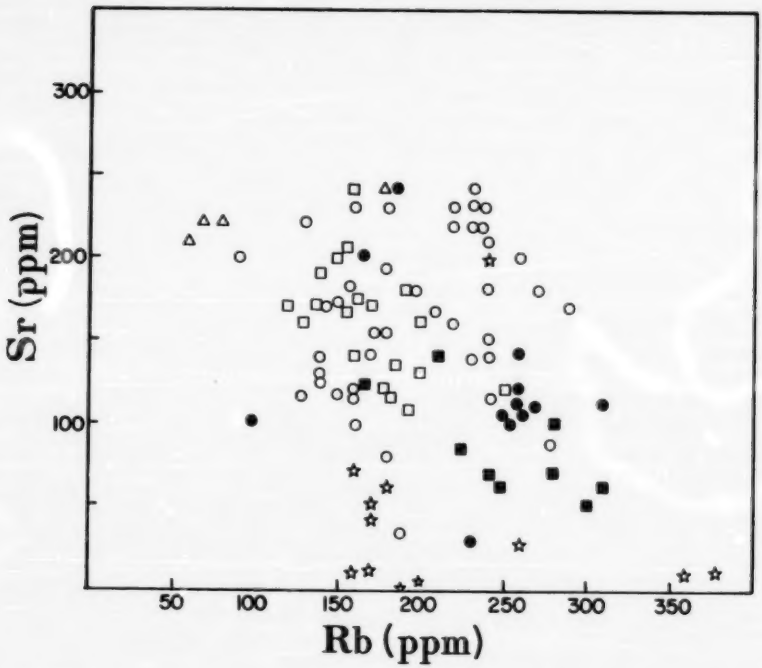

FIGURE 20. Variation of Sr versus Rb. See Figure 14 for symbols.

Tungsten mineralization has also been discovered northwest of the Pokiok Batholith, on Sisson Brook by Kidd Creek Mines Ltd. Wolframite, scheelite, and chalcopyrite occur in a north-south fault zone cutting slates and interbedded mafic and felsic tuffs near the eastern contact of the Nashwaak Granite.

The only occurrence of tin (cassiterite) was reported by Dr. Gesner in granites on the Pokiok River (Bailey 1885) but the exact location is not known.

It is apparent in comparing the trace-element geochemistry of the granites of the Pokiok Batholith to known mineralized granites that they lack the high degree of trace-element specialization which is characteristic of tin-bearing granites. The depth of intrusion which is indicated for the granites in the batholith at the present erosional level is too deep for any model of granophile mineralization. It is quite possible that the now eroded upper portions of the Pokiok Batholith may have fractionated into the specialized granites which typically host Sn-W-Mo deposits in the apical parts of plutons. The presence of hypabyssal leucogranite dykes at the margins of the batholith north of the Saint John River are indicative of a higher level of intrusion at the waning stages of magmatism in the batholith. These dykes are aplitic to pegmatoid and evidently represent the residual saturated melt of the batholith. Their preservation at the present erosional

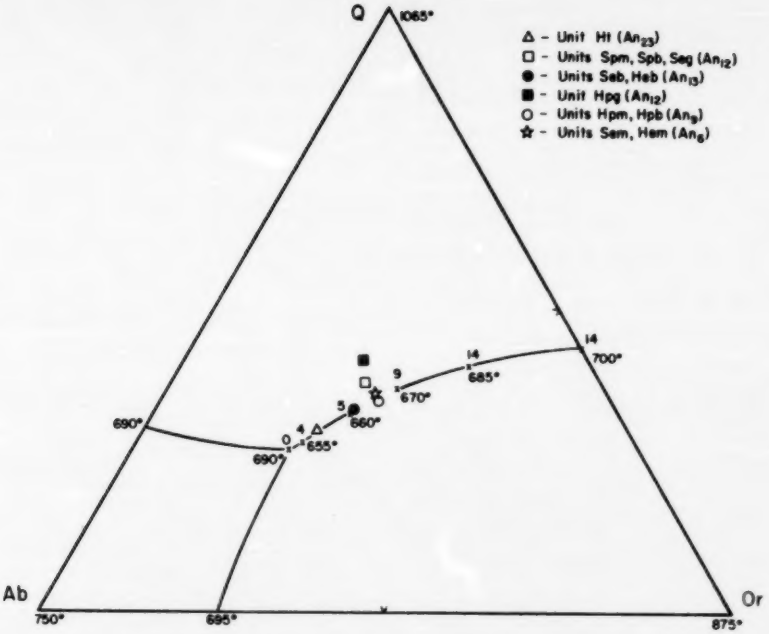

FIGURE 21. Projection of phase relationships through anorthite apex in quartz-plagioclase-alkali feldspar system at 5 kilobars water pressure (after Winkler et al. 1975). Numbers represent anorthite and temperatures in Centigrade at specific points. Symbols with anorthite contents in brackets represent norms of average analyses from Table 3.

level suggests either that the area north of the Saint John River represents a shallower depth of intrusion for both the plutonic and dyke rocks or that uplift and erosion had been sufficiently rapid in this area as to reduce the lithostatic load to a hypabyssal regime through the duration of magmatism in this area. These dyke rocks are associated with minor late scheelite mineralization in the Coac Stream area and probably elsewhere. The expected trace-element specialization in these rocks has apparently not been produced, however, perhaps because saturation of the residual melt occurred too late in the magmatic history to sufficiently concentrate the granophile elements in the volumetrically small percentage of late hypabyssal leucogranite dykes. The scattered mineral occurrences in late structures near the margins of the northern part of the batholith may be expected from these conclusions.

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APPENDIX I

CHEMICAL ANALYSES AND NORMS

*	-	altered	p	-	pegmatitic dyke
x	-	mafic xenolith	g	-	granitic dyke
( )	-	duplicate analyses	m	-	mafic dyke
a	-	aplitic dyke	n/d	-	not detected

Trace Elements: gold is in ppb
all others are in ppm

Map Unit	Ht						Spm			
Sample Number	1	2	3	4	5[a]	6[a]	7	8	9	10
SiO_2	68.40	62.80	62.70	56.90	65.50	74.40	69.50	70.00	71.00	70.60
TiO_2	0.56	0.84	0.80	1.67	0.65	0.06	0.43	0.40	0.38	0.32
Al_2O_3	15.10	16.20	16.20	15.50	15.70	13.70	14.60	14.50	14.70	14.10
Fe_2O_3	1.17	1.77	1.63	2.71	1.12	0.30	0.65	1.00	0.77	0.67
FeO	2.00	2.70	2.60	5.20	2.50	0.40	2.00	1.60	1.70	1.30
MnO	0.08	0.08	0.07	0.14	0.08	0.06	0.08	0.09	0.07	0.07
MgO	1.23	2.05	1.96	3.88	1.60	n/d	0.89	0.68	0.65	0.65
CaO	3.12	4.29	4.34	5.13	3.75	0.47	2.23	1.82	1.87	1.86
Na_2O	3.35	3.56	3.79	3.00	3.94	3.98	3.15	3.04	3.24	3.14
K_2O	2.93	2.71	2.60	2.65	1.81	3.70	3.99	4.43	4.32	3.97
P_2O_5	0.16	0.22	0.19	0.39	0.20	0.19	0.19	0.19	0.13	0.14
H_2O+	0.60	-	-	-	0.80	0.30	0.40	0.70	0.60	0.50
H_2O^-	0.10	-	-	-	0.10	0.40	n/d	0.10	0.20	0.20
CO_2	0.20	-	-	-	0.10	0.10	0.10	0.20	0.20	0.10
L.O.I.	-	0.85	0.93	1.00	-	-	-	-	-	-
TOTAL	99.00	98.07	97.81	98.17	98.05	98.06	98.21	98.75	99.83	97.62
Q	20.30	19.60	18.27	12.19	20.12	37.37	20.03	30.03	30.45	32.06
C	1.15	0.14	-	-	0.95	2.82	1.53	1.89	1.62	1.64
Or	17.67	16.49	15.99	16.13	11.03	22.50	24.15	26.81	25.86	24.25
Ab	28.89	30.98	33.35	26.12	34.35	34.62	27.28	26.31	27.74	27.44
An	14.71	20.41	20.29	21.61	17.82	1.12	10.05	7.97	8.53	8.58
Di	-	-	0.41	1.11	-	-	-	-	-	-
He	-	-	0.26	0.48	-	-	-	-	-	-
En	3.12	5.25	4.89	9.43	4.11	0.05	2.27	1.73	1.64	1.67
Fs	1.97	2.32	3.56	4.70	3.20	0.51	2.64	1.56	2.01	1.48
Mt	1.73	2.64	2.38	4.04	1.67	0.45	0.97	1.48	1.13	1.00
Il	1.08	1.64	0.16	3.26	1.27	0.12	0.84	0.78	0.73	0.63
Hm	-	-	-	-	-	-	-	-	-	-
Ap	0.38	0.53	0.46	0.93	0.48	0.45	0.45	0.45	0.31	0.34
Ru	-	-	-	-	-	-	-	-	-	-
Rb	180	70	80	60	90	260	190	250	180	200
Sr	240	220	220	210	310	30	180	120	120	130
Zr	180	210	170	270	350	n/d	180	150	180	120
Ba	200	350	450	450	350	n/d	200	300	300	200
Ce	58	-	-	-	83	-	51	62	54	55
U	3.1	2.9	2.9	2.7	3.0	4.1	2.0	2.5	3.8	2.3
Th	14	-	-	-	12	2	11	11	10	9
F	420	500	490	600	360	490	700	430	370	350
Li	-	17	23	20	-	-	-	-	-	-
Au	2	n/d	3	n/d	n/d	n/d	1	n/d	n/d	n/d
Cu	13	-	-	-	15	2	12	13	8	11
Mo	n/d	4	4	4	n/d	n/d	n/d	n/d	n/d	n/d
Sn	n/d	n/d	n/d	n/d	n/d	15	n/d	n/d	n/d	n/d
W	n/d	5	3	1	5	22	n/d	5	5	5
Cr	-	140	100	160	-	200	-	-	-	-

Map Unit	Spa						Seg	Spb		
Sample Number	11	12	13	14	15	16	17	18	19	20
SiO_2	69.40	69.70	68.50	65.70	67.80	66.60	66.60	69.00	69.90	69.80
TiO_2	0.54	0.73	0.70	0.54	0.67	0.67	0.73	0.48	0.50	0.43
Al_2O_3	14.50	13.50	14.90	15.40	14.60	15.20	15.50	14.90	14.80	15.40
Fe_2O_3	1.02	0.79	0.91	1.14	1.06	1.03	0.59	0.91	1.01	2.80
FeO	2.50	3.30	3.50	2.30	3.10	2.80	3.70	1.90	2.20	0.01
MnO	0.08	0.07	0.06	0.10	0.06	0.09	0.07	0.08	0.07	0.08
MgO	0.88	1.12	1.11	1.23	1.00	1.49	1.14	1.07	1.66	1.31
CaO	1.90	2.37	2.15	2.79	2.30	3.12	2.61	2.57	2.83	2.37
Na_2O	2.59	2.59	2.68	3.49	2.80	3.28	2.84	3.28	2.78	3.52
K_2O	4.22	2.53	3.75	3.26	3.50	3.33	3.81	3.63	3.53	3.88
P_2O_5	0.21	0.09	0.23	0.25	0.21	0.24	0.33	0.19	0.16	0.14
H_2O+	0.50	0.50	0.70	0.50	1.00	0.60	0.60	0.50	0.60	0.49
H_2O^-	0.20	0.10	n/d	0.10	0.20	0.10	0.20	0.10	0.10	-
CO_2	0.20	0.20	0.10	0.10	0.40	0.10	0.10	0.20	0.10	0.05
L.O.I.	-	-	-	-	-	-	-	-	-	-
TOTAL	98.74	97.59	99.29	96.90	98.70	98.55	99.02	98.71	97.24	100.28
Q	32.72	37.60	31.30	25.61	31.45	25.56	27.31	29.08	29.01	27.92
C	2.78	2.49	3.12	1.72	2.60	1.12	2.81	1.38	1.70	1.44
Or	25.51	15.46	22.52	20.04	21.32	20.13	23.02	21.91	21.65	23.03
Ab	22.40	22.64	23.02	30.69	24.40	28.36	24.54	28.32	24.39	29.89
An	8.23	11.54	9.30	12.69	10.34	14.21	11.02	17.74	13.47	10.88
Di	-	-	-	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-	-	-
En	2.24	2.88	2.81	3.18	2.57	3.79	2.90	2.72	4.29	3.27
Fs	3.07	4.48	4.70	2.68	3.94	3.42	5.34	2.14	2.60	-
Mt	1.51	1.18	1.34	1.72	1.58	1.53	0.87	1.35	1.52	1.58
Il	1.05	1.43	1.35	1.07	1.31	1.30	1.42	0.93	0.99	0.82
Hm	-	-	-	-	-	-	-	-	-	0.85
Ap	0.50	0.22	0.54	0.06	0.50	0.57	0.78	0.45	0.39	0.33
Ru	-	-	-	-	-	-	-	-	-	-
Rb	190	120	140	200	130	150	140	170	160	180
Sr	180	170	190	160	160	200	170	170	180	118
Zr	180	330	310	200	310	210	320	180	160	130
Ba	200	350	400	200	600	300	650	200	250	250
Ce	51	81	99	53	120	56	97	85	63	-
U	2.0	1.8	2.4	2.7	1.9	3.6	2.1	2.2	2.5	2.8
Th	11	18	16	11	22	7	15	15	14	-
F	700	500	510	430	430	570	590	470	420	610
Li	-	-	-	-	-	-	-	-	-	-
Au	1	n/d	n/d	n/d	n/d	n/d	1	1	n/d	-
Cu	12	15	19	22	24	14	18	17	30	16
Mo	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	-
Sn	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	-
W	n/d	n/d	5	n/d	n/d	n/d	5	n/d	n/d	-
Cr	-	-	-	-	-	-	-	-	-	-

Map Unit	Spb	Hpb								
Sample Number	21*	22	23	24	25	26	27	28	29	30
SiO_2	70.00	68.90	67.80	72.90	69.20	69.60	67.30	68.30	72.50	70.20
TiO_2	0.56	0.48	0.64	0.33	0.35	0.58	0.43	0.50	0.43	0.49
Al_2O_3	14.80	14.60	14.40	14.10	15.30	14.70	15.50	14.90	13.80	14.00
Fe_2O_3	2.10	0.80	1.43	1.09	1.52	1.16	0.61	1.26	1.02	1.45
FeO	1.60	1.50	2.10	0.80	0.50	1.90	1.80	1.40	1.50	1.30
MnO	0.10	0.09	0.09	0.07	0.05	0.09	0.08	0.07	0.06	0.04
MgO	1.63	0.91	1.12	0.50	0.54	1.20	0.78	0.89	0.48	0.72
CaO	3.06	2.30	2.42	1.71	1.46	2.61	2.26	2.37	1.50	1.06
Na_2O	3.78	3.47	3.45	3.54	3.35	3.56	3.26	3.30	2.92	2.57
K_2O	2.65	3.90	3.49	4.09	4.59	3.81	4.61	4.35	4.58	4.67
P_2O_5	0.26	0.19	0.23	0.14	0.19	0.21	0.16	0.17	0.14	0.11
H_2O+	0.49	0.30	0.40	0.40	0.70	0.60	0.30	0.50	0.40	0.40
H_2O^-	-	0.20	0.20	0.20	0.20	n/d	0.20	n/d	0.10	n/d
CO_2	0.09	0.20	0.30	0.20	0.30	0.10	0.20	-	0.20	0.10
L.O.I.	-	-	-	-	-	-	-	-	-	-
TOTAL	101.12	97.84	97.97	100.17	98.15	100.32	97.39	98.21	99.63	97.11
Q	29.20	28.16	28.14	32.80	29.61	26.87	24.90	26.80	34.20	25.32
C	0.77	0.97	1.13	1.08	2.70	0.48	1.47	0.88	1.66	3.16
Or	15.59	23.75	21.24	24.37	27.98	22.67	28.17	26.39	27.38	28.59
Ab	31.81	30.22	30.04	30.17	29.21	30.30	28.50	28.63	24.97	22.51
An	13.41	10.47	10.81	7.62	6.18	11.64	10.50	10.92	6.60	4.70
Di	-	-	-	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-	-	-
En	4.04	2.33	2.87	1.25	1.39	3.01	2.01	2.27	1.21	1.86
Fs	0.56	1.51	1.84	0.16	-	1.75	2.31	0.86	1.33	0.47
Mt	2.97	1.94	2.13	1.59	0.78	1.69	0.90	1.87	1.50	2.18
Il	1.06	0.94	1.25	0.63	0.69	1.11	0.84	0.97	0.83	0.96
Hm	-	-	-	-	1.03	-	-	-	-	-
Ap	0.60	0.45	0.55	0.33	0.45	0.49	0.38	0.40	0.33	0.26
Ru	-	-	-	-	-	-	-	-	-	-
Rb	180	220	220	240	260	180	230	230	240	190
Sr	147	220	230	150	200	230	220	240	140	180
Zr	130	190	250	120	180	210	170	190	210	200
Ba	250	350	200	50	400	300	550	400	350	250
Ce	84	96	130	62	74	120	97	61	67	100
U	2.1	5.2	5.1	5.0	5.7	3.9	4.0	5.5	5.4	3.6
Th	14	32	17	14	18	18	18	14	15	21
F	490	530	950	470	420	670	670	740	550	960
Li	-	-	-	-	-	-	-	-	-	-
Au	-	n/d	2	n/d	n/d	n/d	3	n/d	1	n/d
Cu	24	18	14	5	8	7	10	14	5	12
Mo	-	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Sn	n/d	3	3	3	n/d	n/d	n/d	n/d	3	n/d
W	-	5	n/d	n/d	5	n/d	n/d	n/d	5	n/d
Cr	-	-	-	-	-	-	-	-	-	-

Map Unit	Hpb									
Sample Number	31	32	33	34	35	36	37	38	39	40
SiO_2	67.90	69.30	71.40	67.40	69.60	69.60	72.30	69.30	69.20	72.40
TiO_2	0.49	0.47	0.37	0.56	0.45	0.62	0.27	0.48	0.33	0.53
Al_2O_3	15.00	14.20	13.50	15.00	13.70	15.10	14.60	14.50	14.30	13.80
Fe_2O_3	1.22	0.99	1.57	1.03	1.36	2.00	1.90	0.97	0.65	3.10
FeO	1.40	1.50	0.40	1.90	1.10	1.50	0.01	1.50	1.20	0.01
MnO	0.06	0.06	0.07	0.08	0.06	0.07	0.01	0.08	0.06	0.06
MgO	0.76	0.75	0.46	1.11	0.65	0.93	0.66	0.74	0.55	0.98
CaO	2.08	1.76	1.12	2.63	1.93	2.39	1.33	2.02	1.72	2.05
Na_2O	3.35	3.04	3.48	3.34	3.33	3.86	3.33	3.39	3.21	3.38
K_2O	4.56	5.04	4.89	3.62	4.12	3.84	4.74	4.65	4.95	4.14
P_2O_5	0.17	0.17	0.12	0.20	0.16	0.18	0.18	0.18	0.17	0.16
H_2O+	0.40	0.40	-	0.60	0.40	0.35	0.44	0.30	0.60	0.36
H_2O^-	0.10	0.20	-	0.10	n/d	-	-	n/d	n/d	-
CO_2	0.10	0.10	-	0.30	0.10	0.04	0.09	0.10	0.30	0.07
L.O.I.	-	-	0.62	-	-	-	-	-	-	-
TOTAL	97.59	97.98	98.00	97.87	96.96	100.48	99.86	98.21	97.24	101.04
Q	26.23	28.08	30.48	27.39	30.76	26.32	24.90	26.84	28.00	31.32
C	1.21	0.97	0.75	1.32	0.66	0.68	1.47	0.66	0.97	0.41
Or	27.81	30.65	29.70	22.10	25.26	22.69	28.17	28.12	30.39	24.37
Ab	29.22	26.44	30.24	29.17	29.21	32.63	28.50	29.32	28.19	28.45
An	9.49	7.83	4.90	12.12	8.84	10.67	10.50	9.04	7.70	9.08
Di	-	-	-	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-	-	-
En	1.95	1.92	1.18	2.85	1.68	2.31	2.01	1.88	1.42	2.43
Fs	0.89	1.31	-	1.92	0.28	0.21	2.31	1.34	1.28	-
Mt	1.82	1.48	0.46	1.54	2.04	2.90	0.91	1.44	0.98	1.79
Il	0.96	0.92	0.72	1.10	0.89	1.18	0.84	0.93	0.65	1.00
Hm	-	-	1.30	-	-	-	-	-	-	0.79
Ap	0.41	0.41	0.29	0.48	0.39	0.42	0.38	0.43	0.41	0.37
Ru	-	-	-	-	-	-	-	-	-	-
Rb	230	230	180	230	240	172	242	240	290	174
Sr	230	220	80	230	180	151	115	210	170	154
Zr	230	250	140	180	160	170	-	180	150	240
Ba	350	400	350	350	250	350	300	400	200	450
Ce	110	89	-	92	95	91	85	110	66	110
U	5.8	3.0	6.1	4.8	4.5	2.7	4.1	3.6	5.4	5.0
Th	20	17	-	17	20	13	17	22	13	12
F	640	500	950	680	670	960	620	620	430	910
Li	-	-	47	-	-	-	-	-	-	-
Au	3	n/d	1	n/d	n/d	-	-	2	2	-
Cu	8	7	-	18	12	6	5	8	3	7
Mo	n/d	n/d	4	n/d	n/d	n/d	-	n/d	n/d	n/d
Sn	3	n/d	n/d	n/d	3	-	n/d	n/d	n/d	n/d
W	n/d	n/d	6	n/d	n/d	-	-	5	5	-
Cr	-	-	100	-	-	-	-	-	-	-

Map Unit	Hpb									
Sample Number	41*	42*	43*	44*	45*	46*	47*	48*	49*	50*
SiO_2	68.50	70.60	60.70	69.20	71.50	69.00	69.80	68.20	-	-
TiO_2	0.52	0.51	0.58	0.55	0.52	0.37	0.41	0.37	-	-
Al_2O_3	14.70	14.30	13.10	14.90	13.40	14.80	14.20	14.20	-	-
Fe_2O_3	0.90	0.92	1.06	1.08	0.90	1.14	1.25	1.03	-	-
FeO	1.70	1.60	1.70	1.90	1.70	1.00	1.00	1.00	-	-
MnO	0.08	0.07	0.05	0.08	0.07	0.07	0.07	0.13	-	-
MgO	0.99	1.12	0.99	1.11	0.66	0.80	0.68	1.02	-	-
CaO	1.59	1.82	0.95	1.23	1.02	1.89	2.03	2.55	-	-
Na_2O	2.62	3.12	4.12	3.19	2.60	3.67	3.00	2.88	-	-
K_2O	3.97	3.86	2.66	4.03	4.36	3.69	3.63	2.33	-	-
P_2O_5	0.18	0.18	0.21	0.20	0.17	0.14	0.15	0.16	-	-
H_2O+	0.10	0.80	1.10	1.20	1.20	0.80	1.00	1.90	-	-
H_2O^-	0.10	n/d	0.30	n/d	0.10	n/d	n/d	0.30	-	-
CO_2	0.90	0.20	0.20	0.60	0.70	0.20	0.10	1.50	-	-
L.O.I.	-	-	-	-	-	-	-	-	-	-
TOTAL	96.85	99.10	97.72	99.27	98.90	97.57	97.32	97.57	-	-
Q	34.38	32.56	34.33	31.44	37.39	29.49	34.70	38.04	-	-
C	3.79	2.15	2.31	3.62	3.05	1.72	2.08	2.86	-	-
Or	24.53	23.27	16.37	24.46	26.61	22.60	22.32	14.68	-	-
Ab	23.15	26.91	36.27	27.69	22.70	32.15	26.38	25.96	-	-
An	7.01	8.00	3.47	4.92	4.07	8.76	9.45	12.36	-	-
Di	-	-	-	-	-	-	-	-	-	-
Ne	-	-	-	-	-	-	-	-	-	-
En	2.58	2.84	2.57	2.84	1.70	2.06	1.76	2.71	-	-
Fs	1.74	1.49	1.44	1.89	1.70	0.43	0.27	0.66	-	-
Mt	1.36	1.36	1.60	1.61	1.35	1.71	1.88	1.59	-	-
Il	1.03	0.99	1.15	1.07	1.02	0.73	0.81	0.75	-	-
Hm	-	-	-	-	-	-	-	-	-	-
Ap	0.44	0.43	0.51	0.48	0.41	0.34	0.36	0.40	-	-
Ru	-	-	-	-	-	-	-	-	-	-
Rb	270	180	150	260	190	210	250	170	-	-
Sr	70	220	60	120	110	340	190	150	-	-
Zr	190	210	230	170	240	150	150	150	-	-
Ba	200	300	150	300	350	200	150	n/d	-	-
Ce	88	91	69	97	120	65	64	70	-	-
U	8.3	5.0	6.6	5.1	4.6	8.2	4.1	4.0	3.3	13.3
Th	21	18	14	18	19	13	16	16	16	20
F	520	640	1900	690	420	590	410	420	-	-
Li	-	-	-	-	-	-	-	-	-	-
Au	n/d	3	n/d	1	n/d	3	n/d	n/d	-	-
Cu	8	8	9	6	7	5	5	8	-	-
Mo	n/d	n/d	4	n/d	n/d	n/d	n/d	n/d	8	24
Sn	3	n/d	n/d	n/d	n/d	n/d	n/d	3	n/d	n/d
W	5	n/d	10	n/d	5	n/d	n/d	5	29	14
Cr	-	-	-	-	-	-	-	-	-	-

Map Unit	Hpb					Hpm				
Sample Number	51*	52	53	(54	55)	56	57	58	59	(60[A]
SiO_2	63.70	64.60	70.20	68.70	68.70	70.50	71.30	68.50	69.70	75.10
TiO_2	0.91	0.18*	0.49	0.62	0.61	0.43	0.28	0.49	0.40	0.07
Al_2O_3	15.00	15.30	14.00	14.00	14.20	14.00	13.90	14.40	14.40	12.80
Fe_2O_3	1.25	6.60	0.95	1.35	1.05	1.51	0.95	1.08	2.01	0.22
FeO	3.70	0.01	1.80	1.80	2.10	0.80	0.80	1.50	1.20	0.22
MnO	0.11	0.13	0.04	0.07	0.07	0.07	0.06	0.07	0.07	0.01
MgO	2.75	2.12	0.72	0.89	0.91	0.89	0.38	0.91	0.75	0.02
CaO	3.46	2.94	1.06	1.82	2.09	1.82	0.63	2.20	2.01	0.69
Na_2O	3.16	3.89	2.57	3.06	3.42	3.41	3.13	3.42	3.12	3.72
K_2O	2.39	3.33	4.67	4.95	4.27	4.19	4.71	3.80	4.24	3.96
P_2O_5	0.23	1.33*	0.11	0.18	0.18	0.16	0.20	0.16	0.17	0.04
H_2O+	0.60	0.90	0.60	0.77	0.62	-	0.80	0.60	0.50	0.57
H_2O^-	n/d	-	0.10	-	-	-	0.43	0.17	0.10	0.20
CO_2	0.20	0.07	0.10	-	-	-	n/d	n/d	0.30	n/d
L.O.I.	-	-	-	-	-	0.77	-	-	-	-
TOTAL	97.47	101.40	97.41	98.21	98.22	98.55	97.57	97.30	99.27	97.60
Q	24.07	20.48	34.69	27.33	26.80	30.52	34.82	28.90	30.74	38.06
C	1.53	3.14	3.16	0.75	0.59	0.95	3.10	1.08	1.76	1.27
Or	14.62	19.71	28.59	30.05	25.89	25.35	28.92	23.29	25.50	24.19
Ab	27.66	32.93	22.51	26.57	29.65	29.51	27.49	29.98	26.84	32.50
An	16.20	5.88	4.70	8.06	9.42	8.16	1.89	10.22	9.01	3.27
Di	-	-	-	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-	-	-
En	7.08	5.28	1.86	2.28	2.32	2.27	0.98	2.35	1.90	0.05
Fs	4.61	6.71	1.85	1.33	2.16	-	0.35	1.23	0.29	0.09
Mt	1.89	2.44	1.43	2.01	1.56	1.60	1.43	1.62	2.80	0.33
Il	1.79	0.34	0.96	1.21	1.19	0.84	0.55	0.96	0.77	0.14
Hm	-	-	-	-	-	0.44	-	-	-	-
Ap	0.55	3.09	0.26	0.43	0.43	0.38	0.48	0.38	0.40	0.10
Ru	-	-	-	-	-	-	-	-	-	-
Rb	260	235	230	140	130	160	280	210	270	190
Sr	230	138	140	130	120	120	90	170	180	n/d
Zr	280	360	290	180	240	100	80	120	150	n/d
Ba	150	200	600	600	450	250	100	250	250	n/d
Ce	93	76	120	-	-	-	-	-	65	-
U	9.8	2.2	5.2	2.7	2.4	3.7	6.6	3.8	3.7	10.4
Th	16	8	19	-	-	-	17	16	17	9
F	2300	2200	440	840	840	600	590	850	500	310
Li	-	-	-	25	28	36	-	-	-	-
Au	3	-	n/d	3	n/d	n/d	2	1	4	n/d
Cu	9	8	13	-	-	-	4	5	7	6
Mo	n/d	-	n/d	4	4	4	4	4	n/d	4
Sn	3	3	n/d	n/d	n/d	n/d	n/d	n/d	3	n/d
W	n/d	-	5	5	5	2	12	11	n/d	11
Cr	-	-	-	100	-	140	170	180	-	190

Map Unit	Hpm		Hpg							
Sample Number	61[a])	62[a]	63	64	65	66	67	68	69	70
SiO_2	76.20	75.30	67.80	70.40	68.30	65.90	69.80	68.20	72.50	66.10
TiO_2	0.07	0.08	0.76	0.73	0.54	0.94	0.39	0.82	0.71	0.90
Al_2O_3	12.70	13.00	14.70	13.80	15.30	15.10	14.50	14.90	13.40	15.10
Fe_2O_3	0.30	0.54	0.98	1.06	0.98	1.35	1.05	1.02	n/d	1.01
FeO	0.10	0.10	3.50	3.40	2.50	4.00	1.50	3.30	3.60	4.20
MnO	0.01	0.02	0.08	0.07	0.08	0.09	0.06	0.07	0.05	0.08
MgO	0.02	0.02	1.12	1.48	0.99	1.43	0.63	1.24	1.02	1.31
CaO	0.40	0.39	2.50	1.35	2.26	2.81	2.17	2.36	2.24	2.59
Na_2O	3.73	3.42	2.92	1.99	3.21	3.04	3.39	3.06	2.68	2.80
K_2O	3.87	4.46	3.27	4.00	4.15	3.04	3.72	3.02	1.81	3.33
P_2O_5	0.04	0.10	0.21	0.09	0.26	0.26	0.15	0.17	0.06	0.25
H_2O+	0.60	0.40	0.70	0.80	0.40	0.60	0.30	0.70	0.80	0.90
H_2O^-	0.17	n/d	0.10	n/d	n/d	0.10	n/d	0.20	0.20	0.10
CO_2	0.10	0.10	0.13	0.20	0.20	0.10	0.10	0.20	0.40	0.10
L.O.I.	-	-	-	-	-	-	-	-	-	-
TOTAL	98.21	97.93	98.94	99.37	99.17	98.76	97.76	99.26	99.47	98.77
Q	39.93	38.73	30.46	37.31	27.15	27.51	30.86	31.16	42.12	28.48
C	1.79	2.13	2.36	4.01	2.07	2.37	1.34	2.76	3.16	2.92
Or	23.49	27.08	19.77	24.05	24.90	18.36	22.60	18.20	10.92	20.16
Ab	32.39	29.70	25.25	17.12	27.55	26.26	29.46	26.38	23.12	24.25
An	1.77	1.31	11.27	6.21	9.65	12.49	10.05	10.79	10.93	11.28
Di	-	-	-	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-	-	-
En	0.05	0.05	2.85	3.75	2.50	3.64	1.61	3.15	2.54	3.34
Fs	-	-	4.61	4.36	3.08	4.95	1.39	4.07	5.64	5.67
Mt	0.16	0.16	1.45	1.56	1.44	2.00	1.56	1.51	-	1.50
Il	0.14	0.16	1.48	1.41	1.04	1.82	0.76	1.59	1.38	1.75
Hm	0.20	0.44	-	-	-	-	-	-	-	-
Ap	0.10	0.24	0.50	0.21	0.61	0.62	0.36	0.40	0.14	0.67
Ru	-	-	-	-	-	-	-	-	-	-
Rb	160	360	130	140	180	160	170	140	90	150
Sr	10	10	220	140	190	230	140	170	200	170
Zr	30	30	310	290	230	360	200	340	280	360
Ba	n/d	n/d	350	650	400	700	100	700	200	800
Ce	-	13	120	99	87	130	62	130	83	130
U	11.5	5.8	3.2	2.3	2.9	2.6	5.5	3.2	1.9	2.5
Th	8	5	20	17	14	21	11	22	13	21
F	240	230	460	520	650	1000	470	460	290	580
Li	-	-	-	-	-	-	-	-	-	-
Au	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	2	n/d
Cu	7	6	14	22	9	25	7	19	15	18
Mo	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	4	n/d
Sn	n/d	n/d	n/d	n/d	3	n/d	n/d	n/d	4	n/d
W	16	35	n/d	n/d	n/d	n/d	n/d	n/d	n/d	5
Cr	170	-	-	-	-	-	-	-	-	-

Map Unit	Hpg			Seb						
Sample Number	71[x]	72[a]	73[p]	74	75	76	77	78	79	80*
SiO_2	66.50	75.70	75.30	69.80	65.00	69.30	65.60	70.20	68.20	69.30
TiO_2	0.72	0.09	0.04	0.41	0.63	0.58	0.81	0.42	0.24	0.60
Al_2O_3	15.40	13.20	13.10	14.60	15.50	15.30	15.60	15.30	15.70	15.10
Fe_2O_3	1.12	0.58	0.32	1.07	1.23	2.00	5.30	2.80	2.30	3.40
FeO	3.10	0.20	0.10	1.40	2.40	1.60	0.01	0.01	1.60	0.01
MnO	0.10	0.04	0.02	0.07	0.08	0.08	0.01	0.08	0.08	0.01
MgO	1.30	0.10	n/d	1.01	1.49	1.48	2.01	1.13	1.62	1.52
CaO	3.00	0.91	0.63	2.29	3.30	2.75	3.51	2.21	3.02	3.16
Na_2O	4.04	3.27	4.16	3.32	3.40	3.38	4.03	3.45	3.50	3.86
K_2O	1.85	4.75	2.88	4.01	3.16	3.80	2.36	4.29	3.49	3.21
P_2O_5	0.17	0.15	0.20	0.17	0.24	0.26	0.25	0.20	0.28	0.20
H_2O+	0.20	0.30	0.40	0.30	0.60	0.65	0.56	0.56	0.72	0.56
H_2O^-	n/d	n/d	0.10	n/d	0.10	-	-	-	-	-
CO_2	0.10	0.20	0.10	0.20	0.20	0.03	0.06	0.03	0.04	0.04
L.O.I.	-	-	-	-	-	-	-	-	-	-
TOTAL	97.60	99.49	97.35	98.65	97.33	101.21	100.11	100.68	100.79	100.97
Q	27.06	37.18	40.57	29.22	24.23	27.33	22.70	27.84	25.39	26.02
C	1.75	1.39	2.55	1.06	1.10	1.22	0.64	1.44	1.34	0.01
Or	11.25	28.38	17.60	24.17	19.38	22.36	14.07	25.38	20.65	18.94
Ab	35.13	27.95	36.37	28.62	29.83	28.45	34.38	29.19	29.62	32.58
An	14.15	3.57	1.88	10.44	15.35	11.94	15.91	9.66	13.15	14.33
Di	-	-	-	-	-	-	-	-	-	-
Ne	-	-	-	-	-	-	-	-	-	-
En	3.33	0.25	0.05	2.56	3.85	3.67	5.05	2.81	4.04	3.78
Fs	3.87	-	-	1.16	2.59	0.47	1.75	-	2.18	-
Mt	1.67	0.52	0.28	1.58	1.85	2.89	3.38	1.63	2.52	2.09
Il	1.41	0.17	0.08	0.76	1.24	1.10	1.55	0.80	0.46	1.14
Hm	-	0.23	0.14	-	-	-	-	0.80	-	0.65
Ap	0.41	0.35	0.48	0.40	0.58	0.58	0.59	0.46	0.65	0.46
Ru	-	-	-	-	-	-	-	-	-	-
Rb	170	180	170	220	160	162	156	184	154	145
Sr	140	60	40	160	240	175	165	134	205	180
Zr	310	50	60	140	240	170	-	140	190	-
Ba	50	n/d	n/d	250	200	450	-	250	500	-
Ce	79	12	30	63	81	-	-	-	93	-
U	3.3	2.6	4.9	3.9	2.0	3.3	-	3.2	2.0	-
Th	14	3	6	13	10	14	-	-	15	-
F	860	210	260	360	540	640	-	640	400	-
Li	-	-	-	-	-	-	-	-	-	-
Au	n/d	1	1	n/d	5	-	-	-	-	-
Cu	11	7	10	18	24	23	-	12	28	-
Mo	n/d	n/d	n/d	n/d	n/d	-	-	-	-	-
Sn	3	n/d	n/d	n/d	n/d	n/d	-	n/d	n/d	-
W	5	n/d	30	n/d	n/d	-	-	-	-	-
Cr	-	-	-	-	-	-	-	-	-	-

Map Unit	Seb				Heb					Sem
Sample Number	81*	82*	83*	84[9]	(85	86)	87*	88[a]	89[a]	90
SiO_2	73.10	68.60	67.20	68.10	70.10	68.80	-	70.10	70.10	72.60
TiO_2	0.29	0.42	0.91	0.32	0.42	0.44	-	0.19	0.42	0.16
Al_2O_3	14.60	14.20	15.60	14.40	14.80	14.70	-	14.90	14.10	13.80
Fe_2O_3	1.20	1.27	5.20	1.79	1.30	1.30	-	1.14	2.20	0.91
FeO	0.60	1.30	0.01	1.10	1.00	1.10	-	0.10	0.10	0.40
MnO	0.07	0.08	0.11	0.04	0.07	0.07	-	0.03	0.07	0.05
MgO	0.84	1.02	2.06	0.36	0.78	0.91	-	0.30	0.78	0.22
CaO	1.67	2.27	3.43	1.24	1.82	1.90	-	1.06	1.82	1.14
Na_2O	3.21	3.12	3.79	2.09	3.44	3.63	-	3.86	3.44	3.26
K_2O	4.39	3.98	1.91	7.90	4.40	4.52	-	5.95	4.40	4.51
P_2O_5	0.16	0.18	0.25	0.30	0.17	0.17	-	0.19	0.17	0.16
H_2O+	0.47	1.00	0.72	0.40	-	-	-	-	-	0.20
H_2O^-	-	0.10	-	n/d	-	-	-	-	-	n/d
CO_2	0.09	0.90	0.17	0.10	-	-	-	-	-	0.10
L.O.I.	-	-	-	-	0.85	0.70	-	0.70	0.62	-
TOTAL	100.69	98.44	101.36	98.14	99.15	98.24	-	98.52	98.22	97.51
Q	33.19	30.04	27.46	23.85	29.06	25.90	-	23.18	29.37	35.02
C	1.91	1.10	1.66	0.89	1.50	0.81	-	0.65	0.79	1.92
Or	25.93	24.41	11.28	47.86	26.48	27.41	-	35.98	26.67	17.44
Ab	27.12	27.37	32.00	18.11	29.61	31.49	-	33.39	29.83	28.37
An	7.23	10.46	15.35	4.29	8.05	8.52	-	4.10	8.11	4.74
Di	-	-	-	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-	-	-
En	2.09	2.63	5.12	0.92	1.98	2.32	-	0.76	1.99	0.56
Fs	-	0.82	1.34	0.09	0.20	0.36	-	-	-	-
Mt	1.32	1.91	3.49	2.66	1.92	1.93	-	-	0.15	1.02
Il	0.55	0.83	1.73	0.62	0.81	0.86	-	0.28	0.82	0.31
Hm	0.29	-	-	-	-	-	-	1.17	1.87	0.24
Ap	0.37	0.43	0.58	0.71	0.40	0.40	-	0.45	0.40	0.38
Ru	-	-	-	-	-	-	-	0.05	-	-
Rb	223	250	151	240	160	150	-	160	170	280
Sr	110	160	133	200	100	120	-	70	10	70
Zr	90	170	270	240	120	110	-	50	30	100
Ba	250	150	n/d	800	300	300	350	250	100	200
Ce	64	59	-	130	-	-	-	-	-	44
U	7.9	3.0	-	4.6	3.3	3.6	2.7	2.3	3.2	3.1
Th	10	12	-	30	-	-	-	-	-	13
F	500	400	680	290	580	540	540	250	370	260
Li	-	-	-	-	43	45	31	9	12	-
Au	-	3	-	n/d	2	n/d	-	n/d	n/d	1
Cu	7	23	39	5	-	-	-	-	-	12
Mo	-	n/d	-	n/d	4	4	n/d	4	4	n/d
Sn	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
W	-	5	-	n/d	4	6	1	7	5	n/d
Cr	-	-	-	-	100	80	-	80	100	-

Map Unit	Sem									
Sample Number	91	92	93	94	95	96	97	98	99	100*
SiO_2	71.80	72.30	69.40	72.20	72.90	74.00	74.10	70.80	69.90	73.70
TiO_2	0.17	0.15	0.41	0.21	0.07	0.06	0.06	0.36	0.22	0.14
Al_2O_3	14.20	14.20	15.70	15.20	15.70	14.30	14.60	14.50	15.90	13.30
Fe_2O_3	0.69	0.86	0.51	1.40	0.60	1.30	1.50	2.61	2.00	0.66
FeO	0.60	0.30	2.10	0.40	0.01	0.20	0.01	0.01	0.01	0.50
MnO	0.06	0.07	0.09	0.05	0.04	0.06	0.05	0.06	0.05	0.05
MgO	0.30	0.25	0.95	0.48	0.23	0.44	0.42	1.37	0.57	0.26
CaO	1.12	0.80	2.06	1.65	1.09	1.04	1.02	2.11	1.63	0.96
Na_2O	3.28	3.01	3.82	3.88	3.43	3.39	3.57	3.23	4.10	2.85
K_2O	4.37	4.98	3.08	4.27	6.24	4.59	4.94	4.01	4.64	4.80
P_2O_5	0.21	0.27	0.33	0.15	0.03	0.16	0.23	0.17	0.19	0.26
H_2O+	0.60	0.50	0.80	0.41	0.28	0.49	0.45	0.57	0.50	0.20
H_2O^-	0.30	0.20	0.30	-	-	-	-	-	-	0.10
CO_2	0.10	0.10	0.30	0.04	0.04	0.04	0.04	0.04	0.30	0.30
L.O.I.	-	-	-	-	-	-	-	-	-	-
TOTAL	97.80	97.99	99.85	100.34	100.65	100.07	100.99	99.84	99.74	98.08
Q	34.67	35.38	29.61	29.48	26.36	34.42	32.09	30.83	24.67	37.87
C	2.62	3.14	3.18	1.55	1.38	2.25	2.06	1.43	1.63	2.35
Or	26.70	30.31	18.51	25.29	36.79	27.28	29.08	23.92	27.67	29.13
Ab	28.67	26.20	32.83	32.86	28.92	28.81	30.06	27.56	34.98	24.74
An	4.32	2.27	8.19	7.21	5.19	4.13	3.54	9.44	6.90	3.14
Di	-	-	-	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-	-	-
En	0.77	0.64	2.40	1.20	0.57	1.10	1.04	3.44	1.43	0.66
Fs	0.38	-	2.97	-	-	-	-	-	-	0.24
Mt	1.03	0.78	0.75	0.85	-	0.67	0.02	1.37	0.37	0.98
Il	0.33	0.29	0.79	0.40	0.11	0.11	0.11	0.69	0.42	0.27
Hm	-	0.35	-	0.82	0.60	0.84	1.48	0.93	1.48	-
Ap	0.50	0.64	0.77	0.35	0.07	0.37	0.53	0.40	0.44	0.62
Ru	-	-	-	-	0.01	-	-	-	-	-
Rb	310	300	210	214	280	242	245	166	224	280
Sr	60	50	140	91	100	67	61	122	84	60
Zr	120	100	140	110	40	60	100	100	70	80
Ba	100	150	200	350	550	200	250	300	300	n/d
Ce	42	46	37	69	35	65	65	76	-	36
U	3.8	5.5	4.5	6.8	2.0	4.7	4.7	2.6	5.9	4.6
Th	12	11	7	13	7	7	12	12	-	13
F	340	300	580	390	260	260	390	520	450	480
Li	-	-	-	-	-	-	-	-	-	-
Au	n/d	1	n/d	-	-	-	-	-	-	1
Cu	27	20	13	9	9	10	9	17	13	200
Mo	n/d	n/d	n/d	-	-	-	-	-	-	n/d
Sn	n/d	n/d	3	n/d	n/d	n/d	n/d	n/d	n/d	n/d
W	n/d	n/d	n/d	-	-	-	-	-	-	n/d
Cr	-	-	-	-	-	-	-	-	-	-

Map Unit	Sam									
Sample Number	101	102	103	104	105	106	107	108	109	110
SiO_2	70.80	72.20	71.70	72.20	71.50	70.20	71.30	73.30	73.10	72.60
TiO_2	0.35	0.26	0.29	0.29	0.27	0.46	0.31	0.41	0.37	0.24
Al_2O_3	14.20	14.40	14.70	14.80	14.30	15.50	15.60	14.30	14.30	14.90
Fe_2O_3	1.44	0.70	0.86	0.78	1.06	3.10	1.80	1.70	1.70	1.80
FeO	0.80	0.90	0.90	1.00	0.80	0.01	0.40	0.01	0.01	0.01
MnO	0.06	0.07	0.06	0.05	0.06	0.07	0.05	0.06	0.06	0.06
MgO	1.72	1.29	1.39	1.62	1.30	2.93	2.32	1.27	1.09	1.23
CaO	1.72	1.29	1.39	1.62	1.30	2.93	2.32	1.27	1.09	1.23
Na_2O	3.62	3.39	3.30	3.44	3.29	4.28	3.89	3.25	3.47	3.55
K_2O	3.49	4.28	4.52	4.67	4.29	1.92	3.84	5.05	5.03	4.73
P_2O_5	0.12	0.19	0.19	0.18	0.19	0.16	0.10	0.20	0.20	0.21
H_2O+	-	0.40	0.60	0.50	0.60	0.82	0.46	0.39	0.57	0.51
H_2O^-	-	0.20	0.20	0.20	0.10	-	-	-	-	-
CO_2	-	0.20	0.20	0.30	0.10	0.06	0.07	0.04	0.09	0.04
L.O.I.	1.08	-	-	-	-	-	-	-	-	-
TOTAL	98.40	98.95	99.32	100.47	98.31	100.43	100.86	100.55	100.49	100.46
Q	32.83	33.42	32.42	30.48	33.73	30.93	28.11	32.00	31.18	31.00
C	1.67	2.34	2.34	1.58	2.39	1.45	1.06	1.65	1.64	2.21
Or	21.21	25.79	27.19	27.77	26.02	11.42	22.64	29.84	29.80	28.00
Ab	31.47	29.22	28.40	29.26	28.55	36.42	32.80	27.46	29.41	30.06
An	7.96	5.25	5.75	6.90	5.34	13.57	10.82	4.99	4.11	4.73
Di	-	-	-	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-	-	-
En	1.84	1.19	1.04	1.10	1.15	2.30	1.79	1.42	1.25	1.37
Fs	-	0.79	0.59	0.81	0.27	-	-	-	-	-
Mt	1.81	1.03	1.27	1.14	1.58	2.25	0.55	-	-	-
Il	0.68	0.50	0.56	0.55	0.53	0.88	0.59	0.15	0.15	0.21
Hm	0.23	-	-	-	-	0.42	1.41	1.70	1.70	1.77
Ap	0.29	0.45	0.45	0.42	0.45	0.37	0.23	0.46	0.47	0.49
Ru	-	-	-	-	-	-	-	0.33	0.29	0.16
Rb	100	260	310	260	270	185	164	260	262	250
Sr	100	120	110	14-	110	140	200	110	110	104
Zr	150	130	150	150	140	120	110	110	80	100
Ba	350	100	n/d	100	150	100	460	450	250	250
Ce	-	58	81	63	68	49	59	75	79	81
U	3.7	3.3	5.1	4.0	6.1	4.4	2.7	2.3	2.9	3.7
Th	-	13	19	18	14	8	9	14	13	14
F	310	380	700	550	420	940	530	960	640	560
Li	30	-	-	-	-	-	-	-	-	-
Au	n/d	n/d	n/d	n/d	n/d	-	-	-	-	-
Cu	-	6	7	11	19	6	3	7	6	5
Mo	n/d	n/d	n/d	n/d	n/d	-	-	-	-	-
Sn	n/d	3	3	5	3	n/d	n/d	n/d	n/d	n/d
W	7	n/d	10	n/d	5	-	-	-	-	-
Cr	80	-	-	-	-	-	-	-	-	-

Map Unit	Hess						leucogranite dykes		
Sample Number	111	112[a]	113[a]	114	115[a]	116[b]	117	118	119
SiO_2	73.40	73.30	71.60	73.00	73.50	-	73.60	78.30	74.80
TiO_2	0.27	0.05	0.22	0.23	0.14	-	0.18	0.06	0.23
Al_2O_3	13.90	14.00	14.20	13.20	13.70	-	13.60	12.00	12.90
Fe_2O_3	1.90	0.35	1.15	1.20	0.90	-	0.64	0.35	0.42
FeO	-	0.10	0.30	0.30	0.10	-	0.64	0.02	0.10
MnO	0.06	n/d	0.06	0.05	0.04	-	0.06	0.02	0.05
MgO	0.61	0.01	0.31	0.33	0.23	-	0.16	0.04	0.06
CaO	3.24	3.38	2.86	2.41	3.79	-	3.01	4.40	3.54
Na_2O	-	0.48	0.81	0.51	0.79	-	0.35	0.58	0.66
K_2O	4.51	4.44	5.32	5.80	4.51	-	5.25	2.48	5.17
P_2O_5	0.19	0.24	0.26	0.13	0.12	-	0.17	0.03	0.13
H_2O+	0.41	0.50	-	-	-	-	-	-	-
H_2O^-	-	n/d	-	-	-	-	-	-	-
CO_2	0.08	0.10	-	-	-	-	-	-	-
L.O.I.	-	-	1.54	1.08	0.93	-	0.54	1.47	1.08
TOTAL	99.57	96.95	98.63	98.24	98.75	-	98.20	99.75	99.14
Q	34.48	37.54	34.11	36.58	33.21	-	36.11	42.73	33.92
C	1.90	3.46	2.97	2.41	1.46	-	2.80	1.11	0.60
Or	26.86	27.26	32.41	35.31	27.27	-	31.80	14.93	31.19
Ab	27.60	29.68	24.92	20.99	32.78	-	26.08	37.88	30.54
An	4.94	0.84	2.39	1.73	3.20	-	0.64	2.73	2.47
Di	-	-	-	-	-	-	-	-	-
He	-	-	-	-	-	-	-	-	-
En	1.53	0.03	0.80	0.85	0.59	-	0.41	0.10	0.15
Fs	-	-	-	-	-	-	0.47	-	-
Mt	-	0.18	0.54	0.48	0.05	-	0.95	-	-
Il	0.40	0.10	0.43	0.45	0.27	-	0.35	0.09	0.32
Hm	1.78	0.24	0.81	0.91	0.89	-	-	0.36	0.43
Ap	0.44	0.58	0.62	0.31	0.29	-	0.40	0.07	0.31
Ru	0.06	-	-	-	-	-	-	0.02	0.06
Rb	251	380	230	170	170	-	170	100	200
Sr	103	10	30	30	30	-	50	n/d	n/d
Zr	100	20	60	50	50	-	50	20	20
Ba	250	n/d	200	100	100	-	n/d	200	n/d
Ce	83	7	-	-	100	-	-	-	-
U	3.5	2.8	2.2	4.5	4.5	1.4	9.6	12.7	7.3
Th	14	1	-	-	-	-	-	-	-
F	660	310	690	600	600	630	150	350	110
Li	-	-	34	36	36	34	7	12	7
Au	-	n/d	1	3	3	-	n/d	4	n/d
Cu	5	4	-	-	-	-	-	-	-
Mo	-	n/d	4	4	4	n/d	4	4	n/d
Sn	n/d	n/d	n/d	n/d	n/d	3	n/d	3	n/d
W	-	n/d	8	4	4	7	4	4	2
Cr	-	-	100	80	80	-	160	60	80

MAPS
NOT
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CARTES
OMISES